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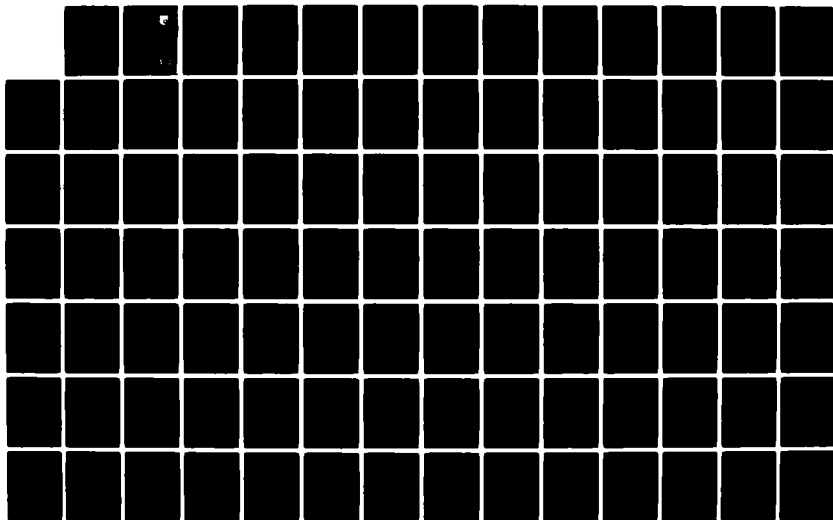
THE CHEMICAL AND PHYSICAL PROPERTIES OF JP-4 FOR 1980 - 1/2
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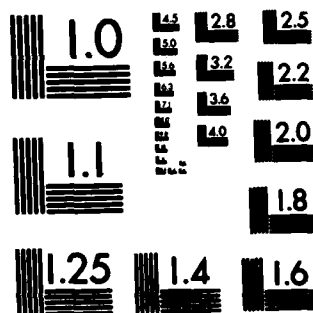
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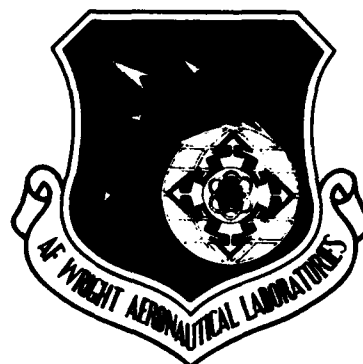


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THE CHEMICAL AND PHYSICAL PROPERTIES
OF JP-4 FOR 1980 - 1981

2Lt William E. Harrison III

Fuels Branch
Fuels and Lubrication Division

June 1982

Report for period July 1980 - June 1981

Approved for public release; distribution unlimited

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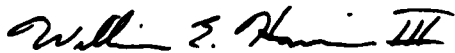
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This technical report has been reviewed and is approved for publication.



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Fuel Properties	Turbine Fuels											
ASTM Test Methods	JP-4 Fuel											
MIL-T-5624L Fuel Specification	Jet Fuel											
Historical Trends	Petroleum Fuel											
"Average" JP-4												
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) <p>This report analyzes the chemical and physical properties of JP-4 purchased worldwide by the Defense Fuel Supply Center (DFSC) for the Air Force during the period July 1980 to June 1981. Data from 2122 Turbine Fuel Test reports were analyzed and summarized in the form of histograms. Summaries include historical trends, current data sorted into districts and states, and a worldwide summary.</p>												

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FOREWORD

This JP-4 Aviation Turbine Fuel Report was prepared by the Fuels Branch of the Aero Propulsion Laboratory, Air Force Wright Aeronautical Laboratories, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. The work was performed under Work Unit 304805FL. Second Lieutenant William E. Harrison III was the project engineer.

This report presents a computer generated statistical summary of the chemical and physical properties of JP-4 aviation turbine fuel procured by the Defense Fuel Supply Center during the period July 1980 to June 1981.

The author wishes to extend his gratitude to Miss Jackie Rooths for her assistance in assembling the data for this report. Appreciation is also extended to Mr. Johnnie Cole, Mr. Stephen Wolanezyk, Mr. Chris Sewell, and Miss Dorothy Boyce for their assistance in coding the data for entry into the computer.



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GLOSSARY OF TERMINOLOGY

Near Specification Band - The reported specification test result which falls between the near specification limit and the specification requirement of MIL-T-5624L.

Near Specification Limit - The value which is one reproducibility limit lower than the maximum specification requirement or one reproducibility limit higher than the minimum specification requirement.

Reproducibility - The reproducibility of a test method is determined by ASTM and is used to determine when test results are suspect. If the results from two laboratories differ by more than the established reproducibility limit, the results are considered suspect.

Specification Limit - The maximum or minimum specification test result that meets the requirements of MIL-T-5624L.

Specification Test - The test method used to measure the properties required to be tested in the requirements of MIL-T-5624L.

LIST OF SYMBOLS

a	Total Acid Number
A	Volume Percent Aromatics
G	API Gravity
H	Hydrogen Content
K_{α}	X-Ray Spectrographic Line for Sulfur
Q	Net Heat of Combustion
Q_p	Net Heat of Combustion on a Sulfur-Free Basis
S	Weight Percent Total Sulfur
V	Average of 10%, 50%, and 90% Recovered Boiling Temperature
x	Weight Percent Mercaptan Sulfur
x_1	Electrical Conductivity
y	Particulate Matter

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BBLS	Barrels
C	Degrees Celsius
DFSC	Defense Fuel Supply Center
F	Degrees Fahrenheit
FBP	Final Boiling Point
g	Gram
Hg	Mercury
IBP	Initial Boiling Point
JFTOT	Jet Fuel Thermal Oxidation Tester
l	Liter
lb	Pound
m	Meter
mg	Milligram
mm	Millimeter
ml	Milliliter
pS	PicoSiemens
WSIM	Water Separation Index Modified

SECTION I

INTRODUCTION

This report summarizes specification chemical and physical properties of JP-4 aviation turbine engine fuels delivered to the Air Force from July 1980 to June 1981. The data were obtained from 2122 Turbine Fuel Test Reports submitted to the Fuels Branch of the Aero Propulsion Laboratory. Similar reports have been prepared since 1960, with the most current report in 1978. The report contains six sections:

Section I is the Introduction.

Section II is a discussion of potential fuel system/turbine engine problems that the specification limits prevent and a synopsis of the American Society for Testing and Materials (ASTM) test methods used to measure the fuel properties.

Section III is a discussion of the relative sample size of the total fuel purchased by the Defense Fuel Supply Center (DFSC) that this report encompasses. A chapter of this section discusses reports with test results outside the specification limits and the possible impact this has on the fuel system/turbine engine.

Section IV is a discussion and graphical display of the property changes between 1960 and 1981.

Section V is the specification test analysis for 1980 - 1981. This section presents the data in the form of histograms for the various specification tests. The data are sorted by district to illustrate the makeup of JP-4 worldwide. An indepth analysis of Districts 1 through 5 (United States) is presented to illustrate state to state variations in JP-4. The final chapter of this section looks at the seasonal variations of JP-4.

Section VI summarizes the data to form an "average" JP-4.

SECTION II

SPECIFICATION TEST AND TEST METHODS

This section contains a short discussion of potential fuel system/turbine engine problems controlled by Military Specification MIL-T-5624L for JP-4 aviation turbine fuel and the American Society for Testing and Materials (ASTM) standard methods for measuring each property (Reference 1).

Seventeen specification tests were studied in this report. These tests are:

- Total acid number, (ASTM D 3242)
 - Test for Total Acidity in Aviation Turbine Fuel
- Volume Percent Aromatics (ASTM D 1319)
 - Test for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator adsorption
- Volume Percent Olefins (ASTM D 1319)
 - Test for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator adsorption
- Weight Percent Mercaptan Sulfur (ASTM D 3227)
 - Test for Mercaptan Sulfur in Gasoline, Kerosene Aviation Turbine and Distillate Fuels (Potentiometric Method)
- Total Weight Percent Sulfur (ASTM D 1266 or D 2622)
 - Test for Sulfur in Petroleum Products (Lamp Method);
 - Test for Sulfur in Petroleum Products (X-Ray Spectrographic Method)
- Distillation Temperature (ASTM D 86 or D 2887)
 - Test for Distillation of Petroleum Products;
 - Test for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
- API Gravity (ASTM D 1298)
 - Test for Density, Specific Gravity, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
- Reid Vapor Pressure (ASTM D 323 or D 2551)
 - Vapor Pressure of Petroleum Products (Reid Method);
 - Test for Vapor Pressure of Petroleum Products (Micro-method)
- Heat of Combustion (ASTM D 3338)
 - Method for Estimation of Heat of Combustion of Aviation Fuels

- Hydrogen Content (ASTM D 3343)
Method for Estimation of Hydrogen Content of Aviation Fuels
- Smoke Point (ASTM D 1322)
Test for Smoke Point of Aviation Turbine Fuels
- Thermal Stability (ASTM D 3241)
Test for Thermal Oxidation Stability of Aviation Turbine Fuels (JFTOT Procedure)
- Existent Gum (ASTM D 381)
Test for Existent Gum in Fuels by Jet Evaporation
- Particulate Matter (ASTM D 2276)
Test for Particulate Contaminant in Aviation Turbine Fuels
- Water Separation Index Modified (ASTM D 2550)
Test for Water Separation Characteristics of Aviation Turbine Fuels
- Volume Percent Fuel System Icing Inhibitor (FED-STD 791 Method 5327, 5330, or 5340)
- Fuel Electrical Conductivity (ASTM D 2624 or D 3114)
Test for Electrical Conductivity of Aviation Turbine Fuels Containing a Static Dissipator Additive;
Test for DC Electrical Conductivity of Hydrocarbon Fuels

The data were compared to the requirements of MIL-T-5624L. The requirements are listed in Table 1 (Reference 2).

Three test methods are included in this report but not found in previous reports. These tests are Distillation Temperature by Simulated Distillation, Volume Percent Icing Inhibitor, and Electrical Conductivity. The test for filtration time was eliminated from this report.

All ASTM test methods have inherent reproducibility limits which form an uncertainty band around the specification limit. In this report, the "near" specification limit is defined as the number that is within the specification limits, but serves as the boundary marker for the reproducibility limits. For example, the reproducibility of the total acid number is $0.0406\sqrt{a}$, where "a" is the average total acid number. If "a" is the specification limit of 0.015 mg KOH/g, the reproducibility of the method is $0.0406(\sqrt{0.015}) = 0.005$. Therefore, the reproducibility band ranges from 0.010 to 0.020 mg KOH/g and the near specification

TABLE 1
CHEMICAL AND PHYSICAL REQUIREMENTS AND TEST METHODS
MIL-T-5624L JP-4 SPECIFICATION

Requirements	Fuel 11/		Test Method ASTM Standards
	Grade JP-4	Grade JP-5	
Color, Saybolt	1/	1/	D 156
Total acid number, mg KOH/g, max	0.015	0.015	D 3242
Aromatics, vol percent, max	25.0	25.0	D 1319
Olefins, vol percent max	5.0	5.0	D 1319
Mercaptan sulfur, weight percent, max 2/	0.001	0.001	D 3227
Sulfur, total weight percent, max	0.40	0.40	D 1266 or D 2622
Distillation temperature, deg C, (D 2887 limits in parentheses)			D 86 3/ or D 2887
Initial boiling point	1/	1/	
10 percent recovered, max temp	1/	205 (185)	
20 percent recovered, max temp	145 (130)	1/	
50 percent recovered, max temp	190 (185)	1/	
90 percent recovered, max temp	245 (250)	1/	
End point, max temp	270 (320)	290 (320)	
Residue, vol percent, max (for D 86)	1.5	1.5	
Loss, vol percent, max (for D 86)	1.5	1.5	
Explosiveness percent, max	--	50	4/ D 93
Flash point, deg C (deg F), min	--	60 (140)	D 1298
Density, kg/l, min (^o API, max) at 15°C	0.751 (57.0)	0.788 (48.0)	
Density, kg/l, max (^o API, min) at 15°C	0.802 (45.0)	0.845 (36.0)	D 1298
Vapor pressure, 37.8°C (100°F) kPa (psi), min	14 (2.0)	--	D 323 or D 2551
Vapor pressure, 37.8°C (100°F) kPa (psi), max	21 (3.0)	--	D 323 or D 2551
Freezing point, deg C (deg F), max	-58 (-72)	-46 (-51)	D 2386
Viscosity, at -20°C, max centistokes	--	8.5 12/	D 445
Heating value, Aniline-gravity product, min, or Net heat of combustion, MJ/kg (Btu/lb) min	5,250 42.8 (18,400)	4,500 42.6 (18,300)	D 1405 D 240, D 2382 or D 3338 5/
hydrogen content, wt percent, min or Smoke point, mm, min	13.6 20.0	13.5 19.0	D 1018, D 3343, or D 3701 6/ D 1322
Copper strip corrosion, 2 hr at 100°C (212°F) max	1b	1b	D 130
Thermal stability: Change in pressure drop, mm of Hg., max Preheater deposit code, less than	25 3	25 3	D 3241 7/
Existent gum, mg/100 ml, max	7.0	7.0	D 381
Particulate matter, mg/liter, max	1.0	1.0	D 2276 8/
Filtration time, minutes, max	15	--	8/
Water reaction Interface rating, max	1b	1b	D 1094
Water separation index, modified, min	10/	85	D 2550
Fuel system icing inhibitor, vol percent min	0.10	0.10	9/
Fuel icing inhibitor, vol percent max	0.15	0.15	9/
Fuel electrical conductivity, pS/m, allowable range	200-600 13/		D 2624 or D 3114

TABLE 1
CHEMICAL AND PHYSICAL REQUIREMENTS AND TEST METHODS (Continued)

- 1/ To be reported - not limited.
- 2/ The mercaptan sulfur determination may be waived at the option of the inspector if the fuel is "doctor sweet" when tested in accordance with the doctor test of ASTM D 484.
- 3/ A condenser temperature of 32° to 40°F (0° to 4°C) shall be used for the distillation of grade JP-5. For JP-4, group 3 test conditions shall be used. Distillation shall not be corrected to 760 mm pressure.
- 4/ Test shall be performed in accordance with method 1151 FEL-STD-791.
- 5/ ASTM D 3338, for calculating the heat of combustion, is only allowed for use with JP-4 fuel. When the fuel distillation test is also performed using ASTM D 2887, the average distillation temperature for use in ASTM D 3338 shall be calculated as follows:

$$v = \frac{10\% + 50\% + 95\%}{3}$$
- 6/ ASTM D 3343, for calculating the hydrogen content of the fuel, is only allowed for use with JP-4 fuel. When the fuel distillation test is also performed using ASTM D 2887, the average distillation temperature for use in D 3343 shall be calculated as follows:

$$v = \frac{10\% + 50\% + 95\%}{3}$$
- 7/ See 4.7.1.1 for ASTM D 3241 test conditions and test limits.
- 8/ A minimum sample size of one gallon shall be filtered. Filtration time will be determined in accordance with the procedure in Appendix A. The procedure in Appendix A may also be used for the determination of particulate matter as an alternate to ASTM D 2276.
- 9/ Test shall be performed with method 5327, 5330, or method 5340 of FED-STD 791.
- 10/ The minimum water separation index, modified, rating for JP-4 shall be 85 with all additives except corrosion inhibitor and electrical conductivity additives present, or 70 with all additives present except for the electrical additives.
- 11/ Requirements and test methods for Grade JP-8 fuel are contained in MIL-T-83133.
- 12/ Until an ASTM thermometer calibrated for the -20°C condition becomes available, this test may be conducted at -34.5°C (-30°F) with a maximum limit of 16.5 centistokes.
- 13/ The fuel electrical conductivity shall range between 200 and 600 picosiemens per meter when measured at the ambient fuel temperature or 85°F, whichever is lower.

limit is 0.010 mg KOH/g. All samples in the range of 0.01 to 0.015 mg KOH/g meet the requirements of MIL-T-5624L and are accepted as specification fuels but also fall within the reproducibility uncertainty of the test method. It should be noted that this problem is taken into account when specification limits are established. Thus, a limit of 0.015 takes into account the uncertainty from 0.015 to 0.020 due to the reproducibility of the method.

1. TOTAL ACIDITY

The total acidity test measures the level of organic acids in the fuel. These acids cause corrosion problems with many of the components of a fuel system, particularly those components which are cadmium plated (References 3 and 4).

The total acidity of a fuel sample is determined by ASTM D 3242 (Reference 1). This method consists of dissolving 100ml of fuel in 100ml of a mixture of toluene and isopropyl alcohol which contains a little water. The sample is blanketed by bubbling nitrogen through it. P-naphtholbenzein is added to the sample as an indicator and the sample is titrated with alcoholic potassium hydroxide until the end point is reached. The method is applicable for an acidity range of 0.000 to 0.100 mg KOH/g. The reproducibility of the method is $0.0406 \sqrt{a}$, where "a" is the total acid number.

2. AROMATICS AND OLEFINS

The test measures both the volume percent aromatics and the volume percent olefins in the sample. A high aromatic content fuel can cause two distinct types of problems in a fuel system. A high aromatic content has deleterious effects on sealants, o-rings, and other elastomer parts of a fuel system. The solvent action of the aromatics causes excessive swelling and softening of elastomers and may result in leaks. A high aromatic content affects the hydrogen content of the fuel (Reference 5). The hydrogen content has been shown to affect the smoke level produced by engines and the life of combustor liners. A high olefin concentration can cause gum formation at ambient storage conditions and may cause some thermal stability problems.

The aromatic and olefin concentration of a fuel is determined by the fluorescent indicator adsorption method, ASTM D 1319 (Reference 1). The method consists of introducing 0.75ml of fuel into a column packed with activated silica gel. A thin layer of silica gel which contains fluorescent dyes is then added. The sample adsorbs onto the silica gel. Isopropanol is added to the column to desorb the sample and force it down the column. The sample is separated into aromatics, olefins, and saturates due to their relative affinity to adsorption onto the column. The fluorescent dyes separate selectively and mark the boundaries of the aromatic, olefin, and saturate fractions when viewed under ultraviolet light. The volume percentage of each component is calculated from the relative length of each zone on the column.

The reproducibility of the method is as follows:

<u>Level of Result, Percent</u>	<u>Aromatics</u>	<u>Olefins</u>
50	4.0	7.7
40 or 60	3.9	7.6
30 or 70	3.7	7.1
20 or 80	3.2	6.2
10 or 90	2.4	4.6
5 or 95	1.7	3.3
1 or 99	0.8	1.5

3. MERCAPTAN SULFUR

The test measures the weight percent mercaptan sulfur in the fuel. Mercaptan sulfur can cause corrosion problems in the fuel system, particularly those parts which are cadmium plated. Mercaptan sulfur attacks sealants, o-rings, and other elastomers used in fuel system. Mercaptan sulfur also solubilizes trace metals such as copper which cause thermal stability problems and accelerates the attack on elastomers.

The mercaptan sulfur content of a fuel sample is determined by ASTM D 3227 (Reference 1). The method consists of dissolving the sample in an alcoholic sodium acetate solution and titrating with a silver nitrate solution, using the potential between a glass reference electrode and a silver/silver sulfide electrode as an indicator. The mercaptan sulfur is precipitated as silver mercaptide and the end point is denoted by a

large change in cell potential. The reproducibility of the method is $.00031 + 0.042x$, where x is the average weight percent mercaptan sulfur.

The mercaptan sulfur test may be waived if the fuel is "doctor sweet". The doctor test, ASTM D 484, consists of combining 10ml of the sample fuel with 5ml of a sodium plumbite solution. The sample is shaken vigorously. A pinch of flowers of sulfur is added and the mixture is shaken vigorously. The sulfur should float at the interface between the fuel and the sodium plumbite solution. If the sample is discolored or the yellow color of the sulfur masked, the test is reported as positive and the sample is declared sour. If the sample color remains unchanged and the color of the sulfur is unchanged or slightly discolored, the test is reported as negative and the sample is declared sweet.

4. TOTAL SULFUR

The test measures the weight percent total sulfur in the fuel. Sulfur can cause corrosive problems since, when it is combusted, SO_2 and SO_3 are formed. These combine with water vapor, which is a combustion product, to form H_2SO_4 . H_2SO_4 attacks the turbine blades of an engine. The SO_2 and SO_3 products also cause air pollution problems. Some sulfur compounds also cause thermal stability problems and corrosion of fuel system components.

The total sulfur of a fuel sample is determined by ASTM D 2624 x-ray spectrographic method (Reference 1). This method consists of placing the sample in the x-ray beam and measuring the intensity of the sulfur K_α line at 5.373 Angstroms. A corrected background at 5.373 Angstroms subtracted from the measured value. The net value is compared to calibration curves to obtain weight percent sulfur. The reproducibility of the method is:

<u>Sulfur Content, Percent</u>	<u>Reproducibility</u>
0.0010 to 0.0050	0.60 x percent S
>0.0050 to 0.0150	0.40 x percent S
>0.0150 to 5.0	0.16 x percent S

The total weight percent sulfur of a fuel sample can also be determined by ASTM D 1266. The method consists of burning the fuel sample in a lamp with an atmosphere of 70 percent carbon dioxide and 30 percent oxygen. The combustion products are flushed with air and hydrogen peroxide, oxidizing the sulfur to sulfuric acid. The sulfur is determined by titration with sodium hydroxide or gravimetrically by precipitation as barium sulfate. The reproducibility of the method is 0.0010 to 0.025S.

5. BOILING RANGE DISTRIBUTION

The boiling range distribution of a fuel is determined by distillation or simulated distillation by gas chromatography. The boiling range distribution relates to the volatility of the fuel, and the volatility affects altitude relight capability and cold start capability. The boiling range distribution allows the refiner to produce a wide boiling fuel and prevents the production of a single component or narrow boiling distribution fuel. The end point is limited to prevent any extremely high boiling components in the fuel.

The boiling range distribution is determined by ASTM D 86 (Reference 1). This method consists of distilling 100ml of fuel denoting the temperatures and volumes of the collected condensate. The reproducibility of the method is as follows:

<u>PERCENT RECOVERED</u>	<u>REPRODUCIBILITY °F</u>
20 to 70	5.2 \pm 7.15
10 to 80	5.4 \pm 4.75
5, 90, 95	3.6 \pm 4.55
IBP	15.5
FBP	19.0

The boiling range distribution of a fuel sample can be determined by ASTM D 2887 simulated distillation. The method consists of determining retention time of the compounds in the fuel by gas chromatography. These values are compared to a run of a known standard, and the boiling range determined. The reproducibility of the method is as follows:

<u>PERCENT RECOVERED</u>	<u>REPRODUCIBILITY °F</u>
IBP	15
5	6
10-40	7
40-90	8
95	10
FBP	24

6. API GRAVITY

The test method measures the API gravity of the fuel. The API gravity is a density measurement of the fuel. This is needed since most fuel is metered volumetrically during aircraft servicing and within turbine engines, but the energy content is primarily dependent on the density. Also, aircraft fuel controls are set on the fuel's density.

The API gravity of a fuel sample is determined by ASTM D 1298 (Reference 1). This method consists of measurement by hydrometer of a sample at constant temperature. The API gravity is calculated as follows:

$$\text{API gravity} = \frac{141.5}{\text{sp gr } 60/60^{\circ}\text{F}} - 131.5$$

The reproducibility of the method from 42 to 78 is 0.3.

7. REID VAPOR PRESSURE

The test measures the Reid vapor pressure. The Reid vapor pressure is a relative measure of vapor lock tendencies. As the Reid vapor pressure increases above the specification limit the tendency to have a vapor lock at altitude in the fuel system increases.

The Reid vapor pressure is determined by ASTM D 323 (Reference 1). This method consists of filling the liquid chamber of the pressure apparatus with chilled sample and connecting this chamber to an air chamber at constant temperature. The apparatus is placed in a constant temperature bath until equilibrium is reached. The pressure read on a pressure gauge attached to the apparatus is the Reid Vapor Pressure. The reproducibility of the method is 0.35 psi.

A second method which can be used to determine the Reid vapor pressure of a sample is ASTM D 2551. The method consists of placing a known volume of sample into an evacuated constant temperature vessel of known volume. The rise in pressure is measured with a manometer when the sample is introduced into the vessel. The Reid vapor pressure is determined from the manometer reading and a correlation factor. The reproducibility of the method is 15mm of Hg.

8. HEAT OF COMBUSTION

The heat of combustion was estimated for all the fuel samples. This test provides information that relates to the range an aircraft can travel with a given mass of fuel. If a fuel meets other specification tests such as smoke point, hydrogen content and distillation range, the heat of combustion will meet requirements.

The heat of combustion of the fuel samples was estimated by ASTM D 3338 (Reference 1). This method was applied to all the data in this report though the refiners of the fuel could have measured the aniline-gravity product or measured the heat of combustion by bomb calorimetry to meet specifications. The estimation method consists of determining the heat of combustion by the equation:

$$Q_p = 16.24G - 3.007A + .017GV - 0.298AG + 0.00053AGV + 17685$$

where

Q_p = net heat of combustion on a sulfur-free basis (btu/lb)

A = volume percent aromatics by ASTM D 1319

G = API gravity

V = average of the boiling points at 10%, 50%, and 90% recovered by ASTM D 86.

A correction was made for sulfur. This correction is:

$$Q = Q_p[1 - 0.015S] + 43.7S$$

where

Q_p = net heat of combustion on a sulfur-free basis (btu/lb)

S = weight percent sulfur in fuel. The reproducibility of the method is 20 Btu per pound.

9. HYDROGEN CONTENT

The weight percent hydrogen of the fuel was estimated. The hydrogen content of the fuel is an important parameter since it correlates to engine performance parameters, combustor liner life, and engine smoke production better than does the alternate specification test, smoke point. Most refiners still perform the smoke point measurement.

The weight percent hydrogen of the fuel samples was estimated using ASTM D 3343 (Reference 1). The refiner may measure hydrogen content by ASTM D 1018 or D 3701 or may estimate hydrogen content using ASTM D 3343 or measure smoke point. Weight percent hydrogen was estimated for all samples with applicable data. The estimation is made by this formula:

$$\%H = 0.06317G - 0.041089A + 0.000072135AV + 0.00005684GV - 0.0004960GA + 10.56$$

where

%H = weight percent hydrogen

G = API gravity

A = volume percent aromatics

V = average boiling point of the 10%, 50%, and 90% recovered distillation data by D 86 distillation.

The reproducibility of the method is 0.10%.

10. SMOKE POINT

The smoke point is a good estimate for the smoke produced from the diffusion flame portion of the combustion process in the combustor. The smoke point does not estimate the turbulent portion of the flame and does not correlate well with the smoke number measured at the exhaust plane of a turbine engine.

The smoke point of a fuel sample is determined by ASTM D 1322 (Reference 1). The method consists of burning a sample of fuel in an enclosed lamp. The maximum flame height that can be achieved without smoking is measured on a scale and is the smoke point of the fuel. The reproducibility of the method is 3 millimeters.

11. EXISTENT GUM

The test measures the existent gum in a fuel sample. The method was originally designed for reciprocating engines to measure gum deposits in fuel intake manifolds and intake valves, and was later incorporated into the JP-4 specification as a hedge against gum deposits. Turbine engines that use prevaporizer fuel tubes are known to be sensitive to existent gum.

The existent gum content of a fuel is determined by ASTM D 381 (Reference 1). This method consists of evaporating the sample by air or steam under controlled temperature and flowrate conditions. The residue is weighed and the existent gum is reported in mg/100ml. The reproducibility of the method for 0 - 7mg/100ml is 3 - 5mg/100ml.

12. THERMAL STABILITY

The test method measures the high temperature thermal stability of fuels. The potential clogging of filters and engine fuel nozzles in the fuel system by deposits is measured in terms of pressure drop across a filter. The test method also measures the deposits that form on a heated tube which correlates to the deposits on fuel system components such as heat exchangers.

The high temperature thermal stability of a fuel sample is determined by ASTM D 3241 using a Jet Fuel Thermal Oxidation Test (JFTOT) which simulates an aircraft fuel system (Reference 1). The fuel is pumped at a fixed volumetric flow rate past a heated polished aluminum tube and then through a stainless steel filter. Fuel degradation products collect on the filter causing a pressure drop and onto the polished tube producing visible deposits. The tube deposits are rated visually.

13. PARTICULATE MATTER

The test measures the particulate matter (i.e., dirt) in a fuel sample. The particulate matter in a fuel sample is limited by requirements to prevent clogging of filters and nozzles in the fuel system and to prevent erosion of orifices in the fuel system and erosion of hot section compo-

nents. Also, particulates can plug up orifices in the fuel control.

The particulate contamination in fuels is determined by ASTM D 2276 (Reference 1). The method consists of filtering a known volume of sample through a preweighed membrane filter. The membrane is washed and dried, then weighed. A control membrane is placed under the test membrane and is treated similarly. The total contaminant is the relative weight increase of the test membrane to the control membrane. The reproducibility of the method is $0.444y + 0.178$ where y is the mean of two tests for particulates.

14. WATER SEPARATION INDEX MODIFIED

A water separation index modified (WSIM) test is performed on fuel samples to rate the ease with which fuel will release entrained or emulsified water when passed through the coalescer of a filter separator. If a fuel contains levels of certain surfactants, the water may be retained in the fuel and not separated out by the filter separator but may settle out in the tanks of aircraft and freeze.

The water separometer ASTM D 2550 consists of a miniature filter-water separator (Reference 1). The test method consists of emulsifying water in the test fuel and then passing the emulsification through a cell containing a glass-fiber coalescer. The amount of emulsified water is measured by the light transmission through the fuel to a photocell. The output of the photocell is read on a meter with a scale from 0 to 100. A high meter reading means that most of the water was removed by the coalescer. The reproducibility of the method between 70 and 100 is 20 and 0 respectively.

15. FUEL SYSTEM ICING INHIBITOR

The amount of fuel system icing inhibitor is measured by this test. Icing inhibitor is used the same as an anti-freeze for any water that may be present in the fuel or fuel system. Icing inhibitor provides a second function in that it works as a fungicide to prevent microorganisms from growing in the water layer of the fuel and using the fuel as a source of food. If the organisms are not prevented from growing in the fuel,

they can cause extensive corrosion and plug filters. Also, the organisms coat fuel tank capacitance type volume probes, giving erroneous fuel gauge readings.

The volume percent fuel system icing inhibitor can be measured by three test methods, Federal Test Method Standard 791, Methods 5327, 5330 and 5340 (Reference 6). Test Method 5327 consists of extracting the icing inhibitor from the fuel with water. The water solution is reacted with an excess of standard potassium dichromate solution in the presence of sulfuric acid. The amount of excess potassium dichromate is determined iodimetrically. The reproducibility of this method is ± 0.005 for the range 0.05 to 0.20 volume percent icing inhibitor.

A second method that can be used to determine the volume percent icing inhibitor in a fuel sample is Method 5330. This test method consists of extracting the icing inhibitor with water from the fuel. Potassium dichromate with sulfuric acid is added to the water solution and the color compared to a color scale to determine the volume percent icing inhibitor.

A third method to determine the volume percent icing inhibitor in a fuel sample is Method 5340. This method consists of extracting the icing inhibitor from the fuel with water. The refractive indices of pure water and the solution of icing inhibitor and water are measured. The volume percent icing inhibitor is calculated from the difference in the refractive indices.

16. ELECTRICAL CONDUCTIVITY

The electrical conductivity of the fuel is measured by this test. The electrical conductivity is critical to ensure that any static charge that might build up within the fuel will rapidly and safely bleed to ground; however, excessive electrical conductivity will affect the accuracy of some fuel level indicators.

The electrical conductivity of the fuel is measured by ASTM D 2624 (Reference 1). This method consists of applying voltage across two

electrodes in a fuel sample and the resulting current expressed as a conductivity value. The reproducibility of the method for a range between 200 and 300 pS/m is 27 and 34 pS/m respectively.

The electrical conductivity of a fuel can also be measured by ASTM D 3114. This method consists of placing the fuel sample in a conductivity cell which is connected in a series to a d-c voltage source and a d-c ammeter. The conductivity is calculated by Ohm's law. The reproducibility of the method is $3.5 + .05x_1$, where x_1 is the measured conductivity.

17. ANTIOXIDANTS

Antioxidant may be added to fuel to prevent the formation of gums and peroxides. The specification requires that 6 to 8.4 pounds of antioxidant per 1000 barrels of fuel (24mg/l) be added to all fuels that have undergone hydrogen treating refining (Reference 2). The refiner has the option to add up to 8.4 pounds of antioxidant to any fuel that is not hydrogen treated.

SECTION III

DATA ORGANIZATION

The data used in this report were obtained worldwide from 2122 Turbine Fuel Test Reports during the period July 1980 through June 1981. Each report represents a separate lot of fuel purchased by the Defense Fuel Supply Center (DFSC) for the United States Air Force.

A computer program was written and used to sort, statistically analyze, and plot the data. The data were sorted by individual specification test into eight worldwide districts. Districts 1 through 5 were further subdivided into the states which comprise the district. The location assigned to each report was the refining location. For data that were obtained from a pipeline, barge, or tanker, the location is the refinery location (if known) or the location the sample was drawn. The computer program also allowed the data to be sorted by month.

The number of samples from each district and the volume of fuel from each district is listed in Table 2. The data in Tables 2 through 7 are based on the reports sent to the Fuels Branch of the Aero Propulsion Laboratory. These reports comprise approximately 65 percent of the volume of the fuel purchased by the DFSC. However, this number is a lower limit since many reports did not include volume data. The sampling of data in this report is very close to the total amount of fuel purchased and is representative of all the fuel purchased by DFSC for the Air Force. Table 3 lists the number of samples and volume information from the East Coast (District 1). Table 4 lists sample size for the Midwest (District 2). Samples from Missouri did not list volumes and may represent a significant volume of fuel that is not included in this summary. Table 5 summarizes the data from the Gulf Coast (District 3). Table 6 summarizes the data from the Rocky Mountain region (District 4). Table 7 summarizes the data from the Pacific region (District 5).

TABLE 2
JP-4 DATA DISTRIBUTION

District	Number of Samples	Percentage of Total Samples	Total Volume BBls	Percentage of Total Volume
1 East Coast	296	14.0	1) 6,183,687	12.6
2 Midwest	666	31.4	2) 11,339,955	17.5
3 Gulf Coast	625	29.4	18,309,560	28.3
4 West	157	7.4	3,017,673	4.7
5 West Coast	253	12.0	14,567,072	22.5
6 Far East	67	3.1	1,599,012	2.5
7 Europe and Near East	25	1.1	1,626,192	2.5
8 South America, West Indies, etc.	37	1.7	6,147,153	9.5

1) Total does not include data from Florida since only four lots of fuel were purchased.

2) Total does not include data from Missouri since volumes were not reported.

TABLE 3
DISTRICT 1 DATA DISTRIBUTION

State	Number of Samples	Percentage Dist	Percentage Total	Total Volume BBls	Percentage of Total Volume	Percentage of Total Volume
Delaware	100	34.1	4.7	4,234,000	51.7	6.1
New York	97	33.1	4.6	1,609,563	19.7	2.5
Pennsylvania	72	24.6	3.4	2,320,124	28.4	3.6
West Virginia	24	8.2	1.1	20,000	0.2	0.03
1) Florida	3	----	---	100,000	----	----

1) Florida was not included since three samples is not statistically significant.

TABLE 4
DISTRICT 2 DATA DISTRIBUTION

State	Number of Samples	Percentage Dist	Percentage Total	Total Volume BBIs	Percentage of Total Volume Dist	Percentage of Total Vol.
Iowa	31	4.7	1.5	601,608	5.3	0.9
Illinois	17	2.6	0.8	286,884	2.5	0.4
Indiana	115	17.3	5.4	2,131,266	18.8	3.3
Kansas	51	7.7	2.4	103,238	0.9	0.2
Kentucky	46	6.9	2.2	618,515	5.5	1.0
Michigan	23	3.5	1.1	313,754	2.8	0.5
Minnesota	47	7.1	2.2	940,588	8.3	1.5
Missouri	25	3.8	1.2	N/A	N/A	N/A
North Dakota	30	4.5	1.4	764,614	6.7	1.2
Ohio	23	3.5	1.1	425,406	3.8	0.7
Oklahoma	196	29.4	9.2	4,596,608	40.5	7.1
South Dakota	30	4.5	1.4	337,800	3.0	0.5
Tennessee	32	4.8	1.5	219,671	1.9	0.3

TABLE 5
DISTRICT 3 DATA DISTRIBUTION

State	Number of Samples	Percentage Dist	Percentage Total	Total Volume BBIs	Percentage Total Volume Dist	Percentage of Total Volume
Alabama	50	8.0	2.4	2,656,815	14.5	4.1
Lousiana	29	4.6	1.4	186,904	1.0	0.3
Mississippi	28	4.5	1.3	224,361	1.2	0.3
Texas	518	82.9	24.4	15,241,479	83.2	23.5

TABLE 6

DISTRICT 4 DATA DISTRIBUTION

State	Number of Samples	Percentage Dist	Percentage Total	Total Volume Bbls	Percentage Total Volume Dist	Percentage of Total Volume
Montana	41	26.1	1.9	1,071,777	35.5	1.7
Utah	65	41.4	3.1	1,182,692	39.2	1.8
Wyoming	51	32.5	2.4	763,204	25.3	1.2

TABLE 7

DISTRICT 5 DATA DISTRIBUTION

State	Number of Samples	Percentage Dist	Percentage Total	Total Volume Bbls	Percentage Total Volume Dist	Percentage of Total Volume
California	203	80.2	9.6	11,865,510	81.5	18.3
Hawaii	50	19.8	2.4	2,701,562	18.5	4.2

1. OUT OF SPECIFICATION DATA

Some of the lots of turbine fuel purchased by DFSC had a property which slightly exceeded the specification limit but was waived and the lot accepted. This section of the report identifies these properties that were waived as well as lots with properties that did not meet the specification limits but whose turbine fuel test report did not denote that the property had been waived.

Two lots of fuel did not meet the total acidity specification requirement. One report contained a waiver, the other did not include one. The specification requirement for this test is 0.015mg KOH/g maximum. The samples contained values of 0.025 and 0.10mg KOH/g. With a high value for the total acidity the potential for corrosion in a fuel system increases, especially components that are cadmium plated.

Four lots of fuel did not meet the olefin specification requirement. None of these reports indicated a waiver. The specification limit is 5.0 volume percent maximum. The samples contained values of 8.0, 9.0, 9.0, and 9.0 volume percent maximum. With a high olefin concentration the likelihood of thermal stability problems as well as storage stability problems increases.

Eleven lots of fuel did not meet the mercaptan sulfur specification requirement. Four lots of fuel contained waivers, the rest of the samples did not. The specification requirement is 0.001 weight percent maximum. The samples contained values of 0.0018, 0.0017, 0.0052, 0.0011, 0.0012, 0.0165, 0.0014, 0.004, and 0.006 weight percent. With a high mercaptan sulfur content the potential of any synthetic rubber component in the fuel system leaking increases. The potential for corrosion and for thermal stability problems also increases.

One lot of fuel did not meet the total sulfur specifications requirement. This sample was not waived. The specification requirement for total sulfur is 0.40 weight percent maximum. The sample contained a value of 0.8 weight percent. With a high sulfur content the likelihood of corrosion problems in the fuel system increases as well as the pollutant emissions.

Two lots of fuel did not meet the D86 distillation 50 percent recovered specification. Both samples were waived. The specification limit for this test is 190 degrees Celsius. The samples contained values of 192 and 192 degrees Celsius. Six lots of fuels did not meet the D2887 distillation 20 percent recovered specification limit. None of these samples were waived. The specification limit for this test is 130 degrees Celsius. The samples contained values of 132, 135, 134, 137, and 134 degrees Celsius. One lot of fuel did not meet the D2887 50 percent recovered specification limit. This sample was not waived. The sample contained a value of 214 degrees Celsius. The specification limit is 185 degrees Celsius. With these high values no major problems would be encountered. However, if the specification limits are not met, altitude relight characteristics and cold starting characteristics are degraded.

Three lots of fuel did not meet the API gravity specification. None of these reports contained waivers. The specification limit for this test is 45.0 minimum, 57.0 maximum. The samples contained values of 57.7, 57.6, and 57.4. This would not cause any major problems with the aircraft.

Three lots of fuel did not meet the Reid vapor pressure system specification. Two reports contained waivers, the other did not. The specification limit is 2.0 minimum and 3.0 maximum. The samples contained values of 3.1, 3.1, and 3.1, respectively. These values would not create any major problems though as the Reid vapor pressure increases the tendency for vapor lock problems increases.

Fourteen samples did not meet the hydrogen content specification limit. The specification limit is 13.6 weight percent minimum. Since all values were calculated by the author, none of them were waived. All were slightly under 13.6 weight percent but all were approximately 13.5. This is not a major problem since the difference from specification may be due to rounding in the calculation.

One sample did not meet the smoke point specification. The sample was not waived. The specification limit is 20.0 minimum. The sample had a value of 126.0 which is totally erroneous and was probably a typographical error on the data sheet.

One lot of fuel did not meet the thermal stability tube deposit code specification. The value was not waived. The specification limit is a deposit color of less than 3. The reported value was 11. This data is erroneous and probably represents a typographical error.

Thirteen lots of fuel did not meet the particulate matter specification. None of these samples were waived. The specification limit is 1.0mg/l. The values reported were 1.43, 2.36, 1.48, 1.48, 1.06, 1.14, 1.16, 1.1, 5.0, 1.4, 1.5, 1.4, and 1.1. This could be a problem since excessive particulates can plug filters and nozzles in a fuel system and erode turbine blades. However, the particulates can be easily removed by filtration.

Eleven lots of fuel did not meet the WSIM specification limit. Six of the reports were waived, the rest were not. The specification limit is 70 minimum. The samples reported values of 66, 66, 68, 65, 66, 65, 68, 66, 61, 65, and 62. The low WSIM values represent a fuel that may not be able to be separated from entrained water by a filter separator and can cause fuel system problems.

Twenty-nine samples did not meet the volume percent icing inhibitor specification. Two of the samples were waived, the rest were not. The specification limit is 0.15 volume percent maximum. All the values reported were slightly higher than this limit. This is not a major problem since extra icing inhibitor is added for barge shipments and the icing inhibitor accumulates in the water bottoms of the tanks.

Eight lots of fuel did not meet the electrical conductivity additive specification. None of these samples were waived. The specification limits are 200 to 600 pS/m. The samples reported values of 20, 840, 720, 172, 640, 180, 190, and 190. The values that are lower than the specification may not contain enough additive to adequately dissipate static charge. The samples with values above the specification limit may cause inaccuracies in fuel level indicator readings.

SECTION IV

HISTORICAL TRENDS

This section summarizes the changes of the chemical and physical properties of JP-4 over the past 21 years. These reports have been prepared by the Fuels Branch of the Aero Propulsion Laboratory for the years 1960, 1963, 1964, 1966, 1970, 1972, 1975, 1978, and 1981 (References 6, 7, 8, 9, 10, 11, 12, 13). Over these years, the chemical and physical requirements for JP-4 have changed to solve operational problems that have cropped up in the field. Also, over the years, new specification tests have been added and others dropped. The graphical summary present illustrates the properties for which several years of data are available. The data are the "average" worldwide values for each property.

1. TOTAL ACID NUMBER

Figure 1 illustrates the trends in total acid number from 1970 to 1981. Over the 11 years, the general trend is toward lower total acid numbers. This trend should result in fewer corrosion problems.

2. VOLUME PERCENT AROMATICS

Figure 2 illustrates the trends in the volume percent aromatics from 1960 through 1981. Over the 21 years, the general trend is increasing aromatic content. These values, though considerably lower than the specification limit, may represent an increase in visible smoke produced by engines, shorter life spans for combustor liners, and increased problems with leaks in fuel system components that are sealed with elastomers.

3. VOLUME PERCENT OLEFINS

Figure 3 illustrates the trends in the volume percent olefins from 1960 through 1981. Over the 21 years, there has been no significant change in the olefin content of fuels.

4. WEIGHT PERCENT MERCAPTAN SULFUR

Figure 4 illustrates the trends in the weight percent mercaptan sulfur

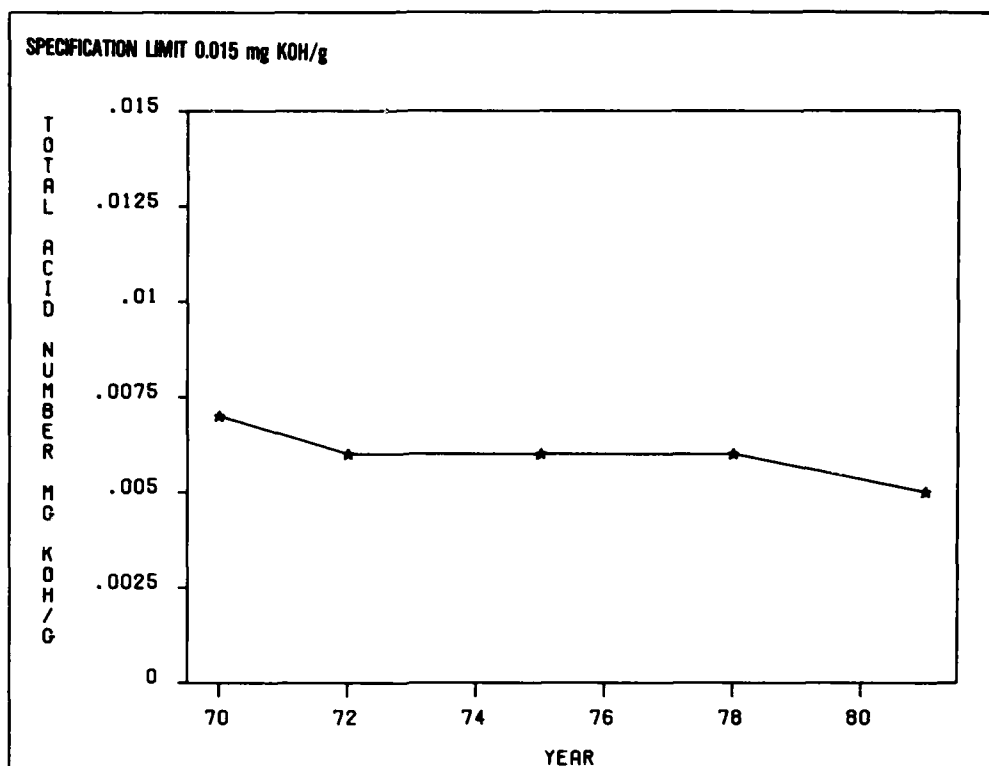


Figure 1. Total Acid Number Variations from 1970 through 1981

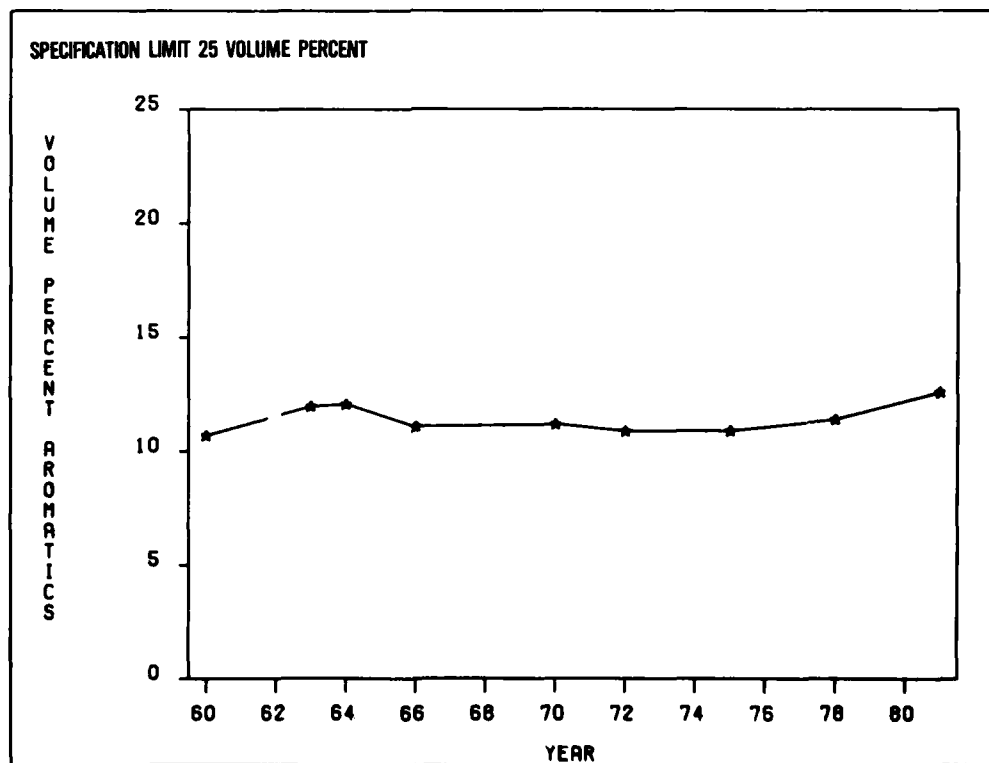


Figure 2. Aromatic Content Variations from 1960 through 1981

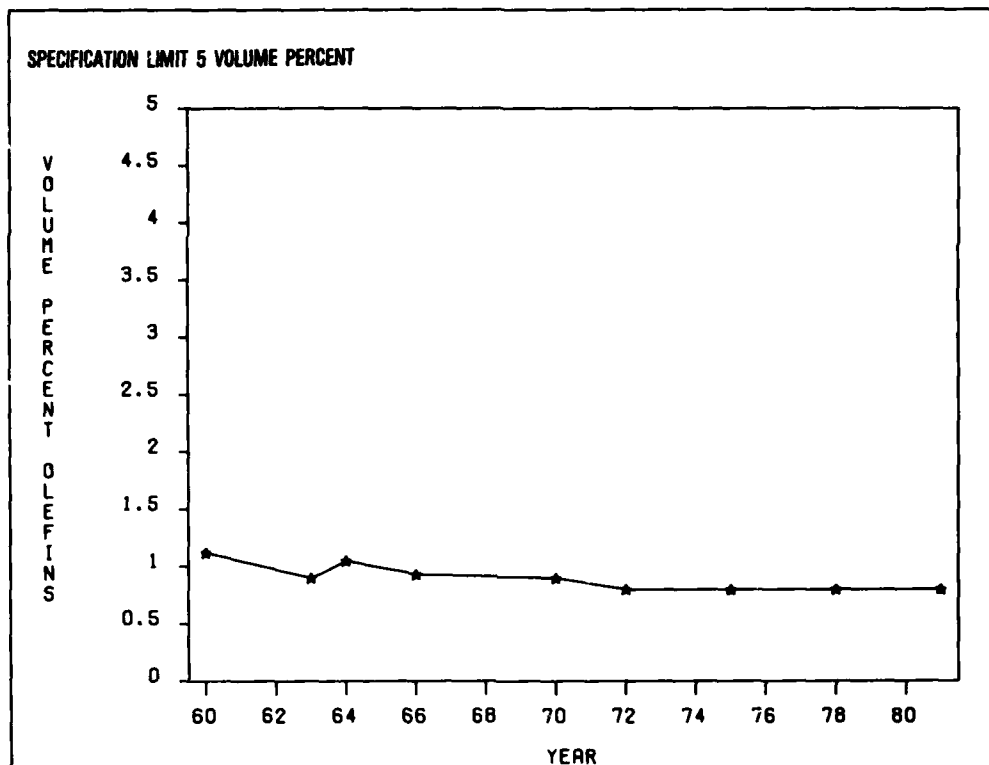


Figure 3. Olefin Content Variations from 1960 through 1981

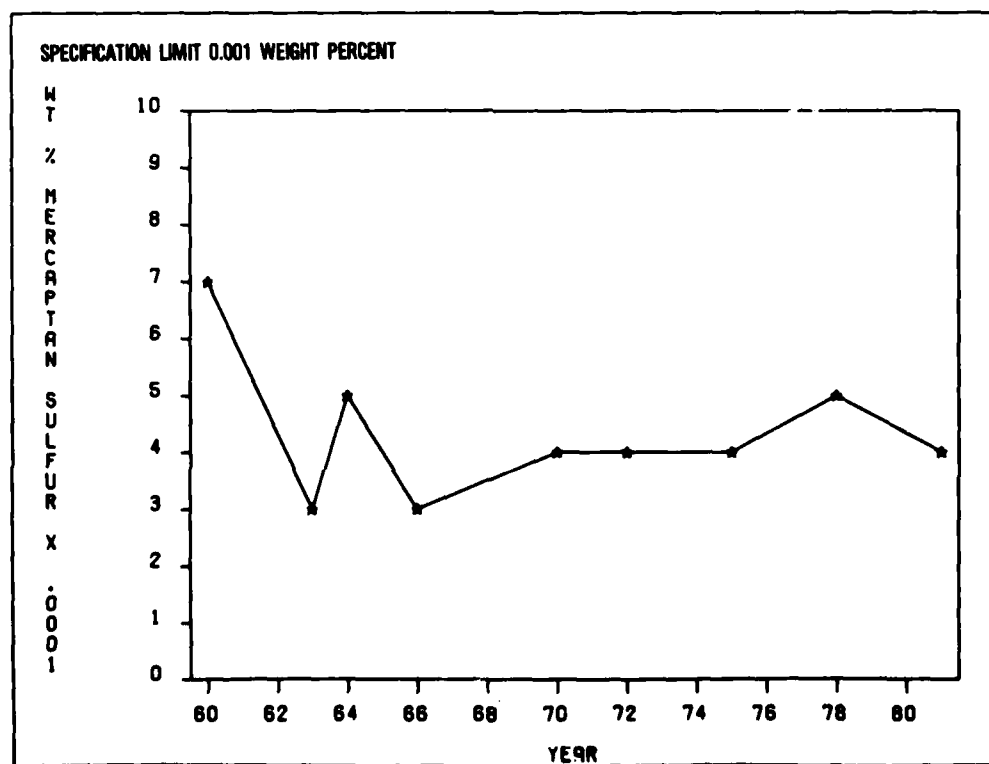


Figure 4. Mercaptan Sulfur Variations from 1960 through 1981

from 1960 through 1981. Over the 21 years, there has been wide variation in mercaptan sulfur.

5. WEIGHT PERCENT TOTAL SULFUR

Figure 5 illustrates the trends in the weight percent total sulfur from 1960 through 1981. Over the 21 years, the sulfur content has remained constant at approximately 0.05 weight percent and well below the requirement limit of 0.4 percent.

6. D 86 DISTILLATION

Figures 6 through 11 illustrate the trends in boiling range distribution from 1960 through 1981. Over the 21 years, the initial boiling point, 10%, 20% and 50% recovered have been decreasing. The 90% recovered data has varied widely from 1960 through 1981 but has remained stable since 1972. The final boiling point varies widely from 1960 through 1981. The trend since 1975 has been a slight increase in the final boiling point. The data illustrate the character of JP-4 changing since 1960 with possible gains in altitude relight capability and cold starting capability.

7. API GRAVITY

Figure 12 illustrates the trends in API gravity from 1960 through 1981. Over the 21 years, the API gravity has been increasing. This trend indicates a slight decrease in the density of the JP-4.

8. REID VAPOR PRESSURE

Figure 13 illustrates the trends in Reid vapor pressure from 1960 through 1981. Over the 21 years, the Reid vapor pressure has remained constant at 2.6 psi.

9. HEAT OF COMBUSTION

Figure 14 illustrates the trends in the net heat of combustion from 1970 through 1981. Over the 11 years, the heat of combustion has remained constant at approximately 18,700 Btu/lb.

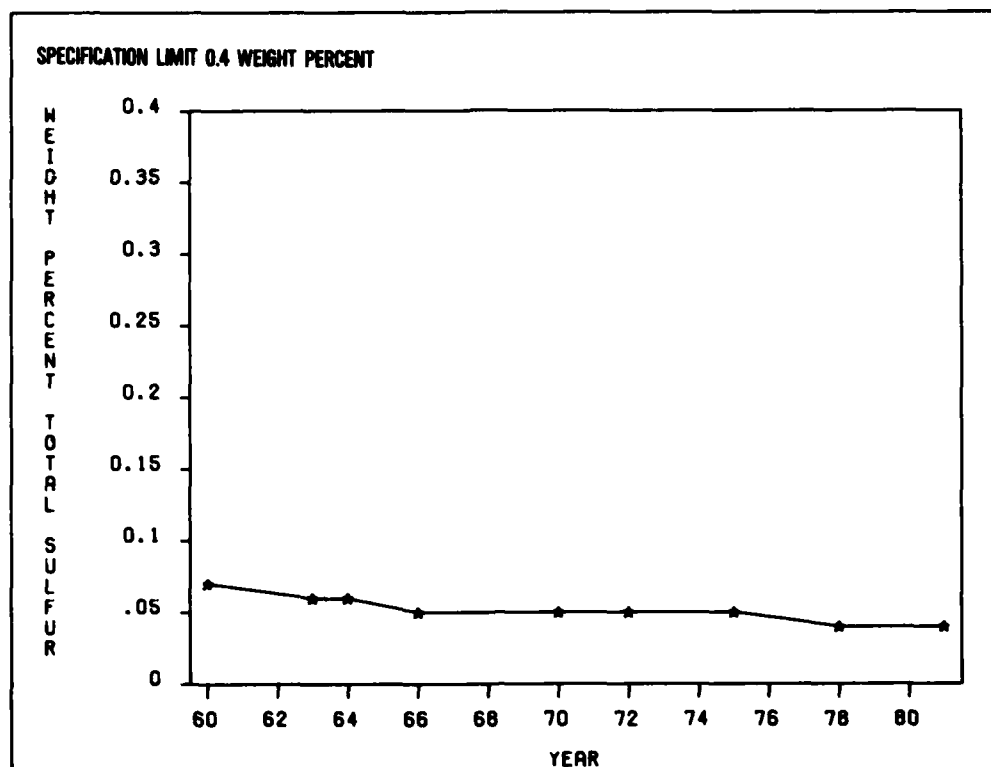


Figure 5. Total Sulfur Variations from 1960 through 1981

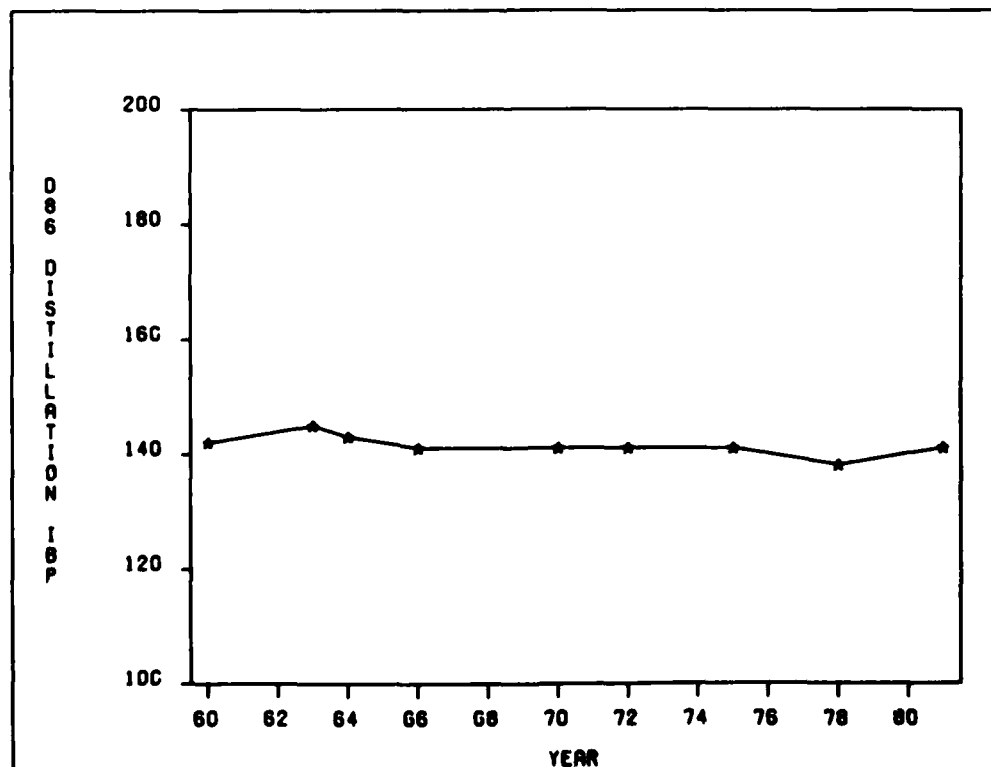


Figure 6. D 86 Distillation Initial Boiling Point Variations from 1960 through 1981

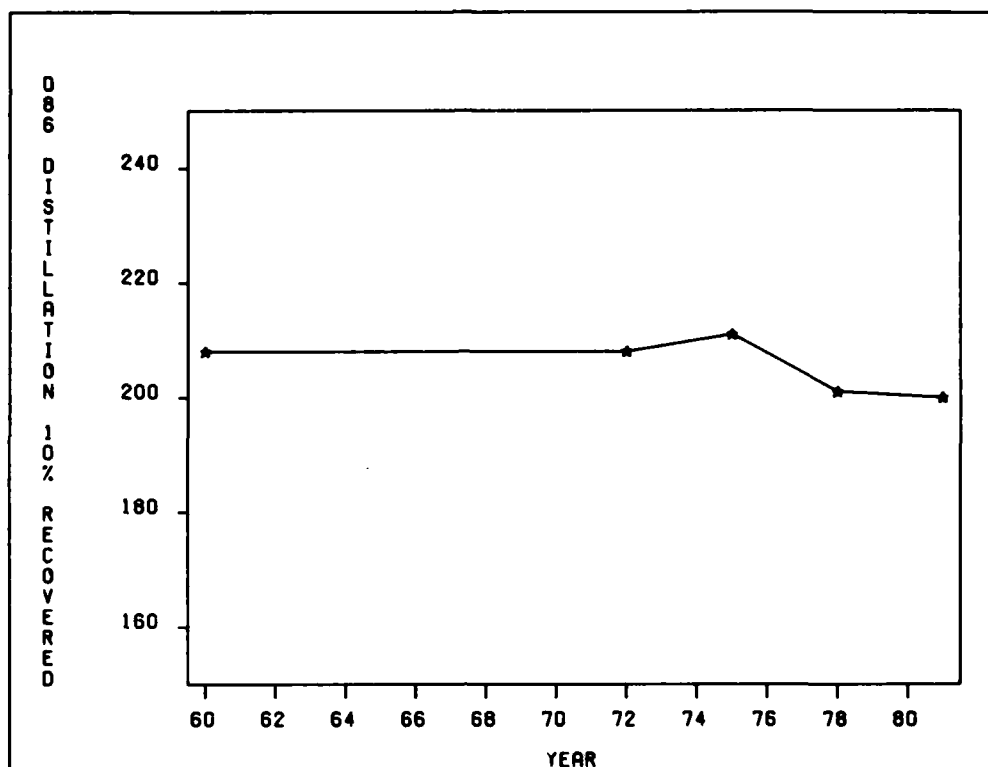


Figure 7. D 86 Distillation 10% Recovered Variations from 1960 through 1981

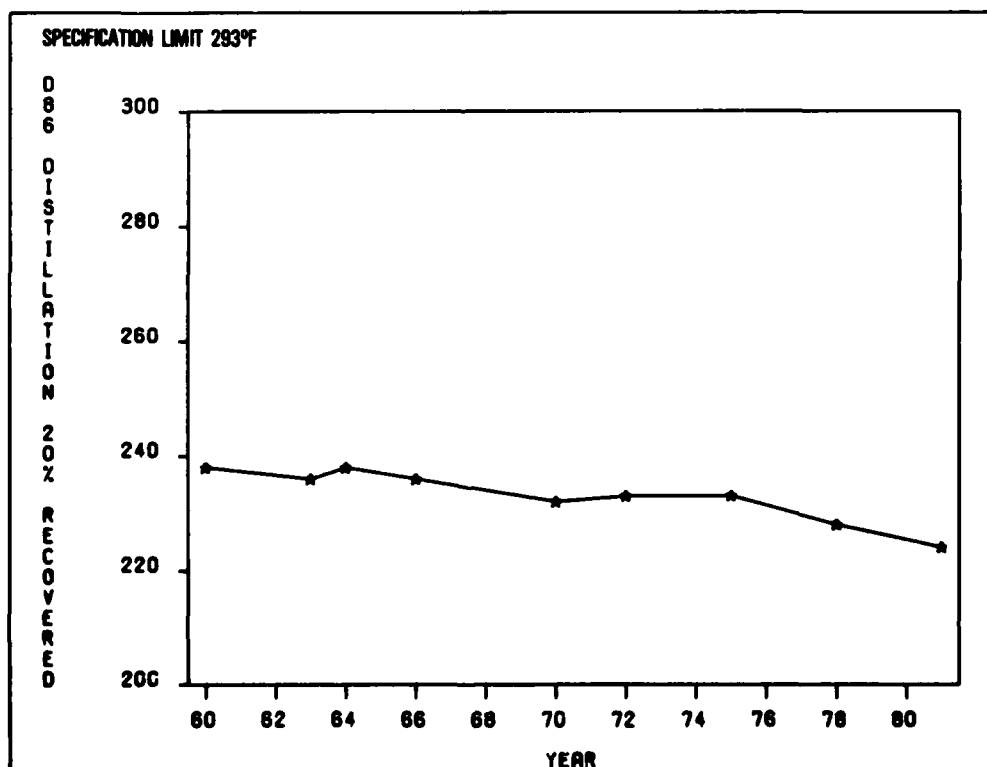


Figure 8. D 86 Distillation 20% Recovered Variations from 1960 through 1981

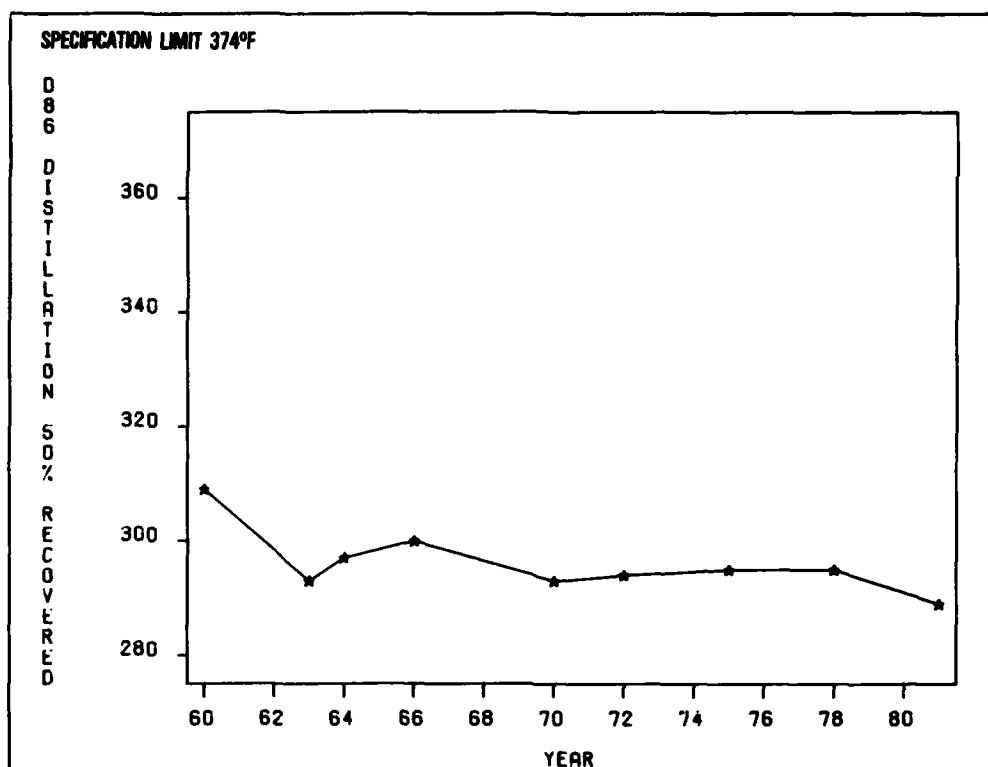


Figure 9. D 86 Distillation 50% Recovered Variations from 1960 through 1981

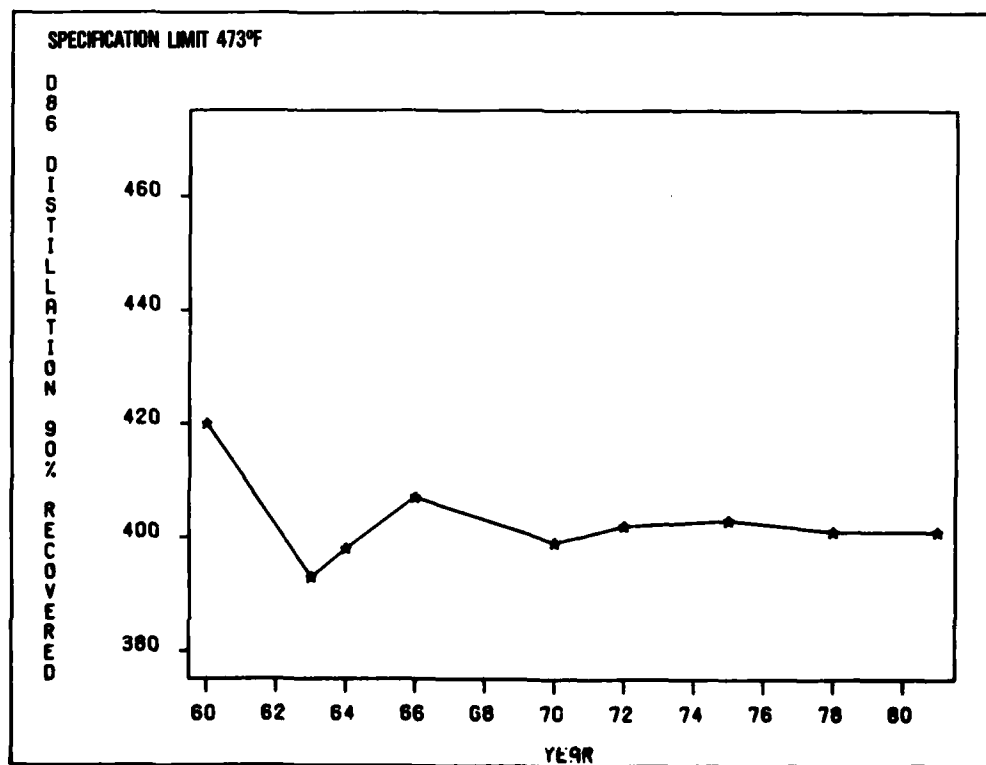


Figure 10. D 86 Distillation 90% Recovered Variations from 1960 through 1981

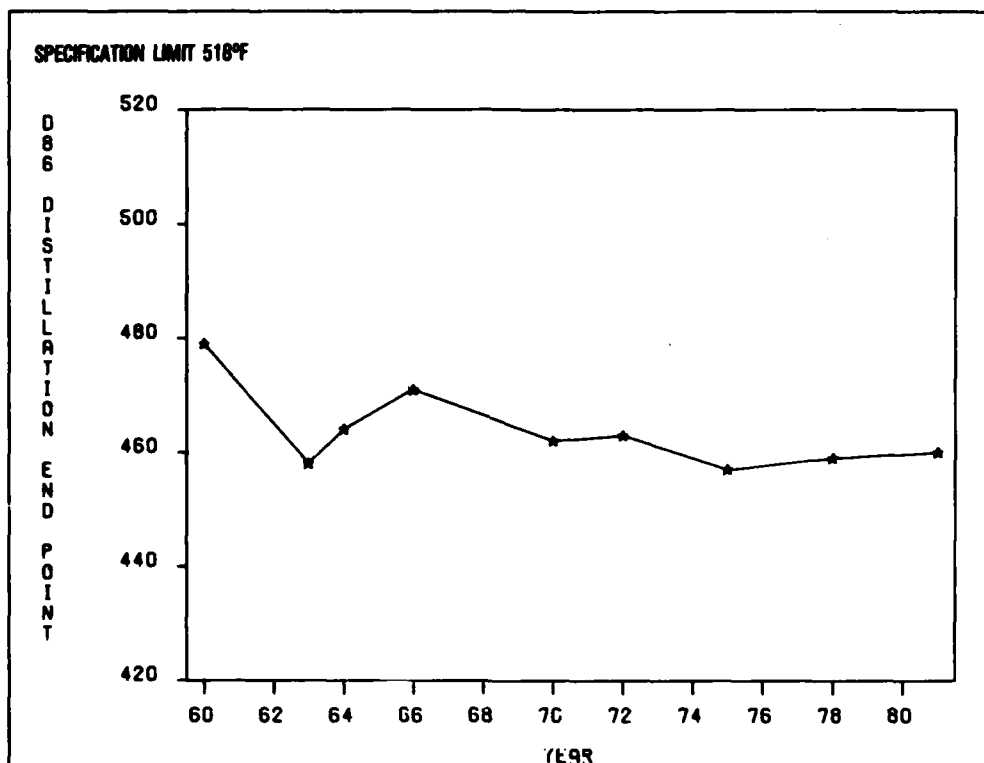


Figure 11. D 86 Distillation Final Boiling Point Variations from 1960 through 1981

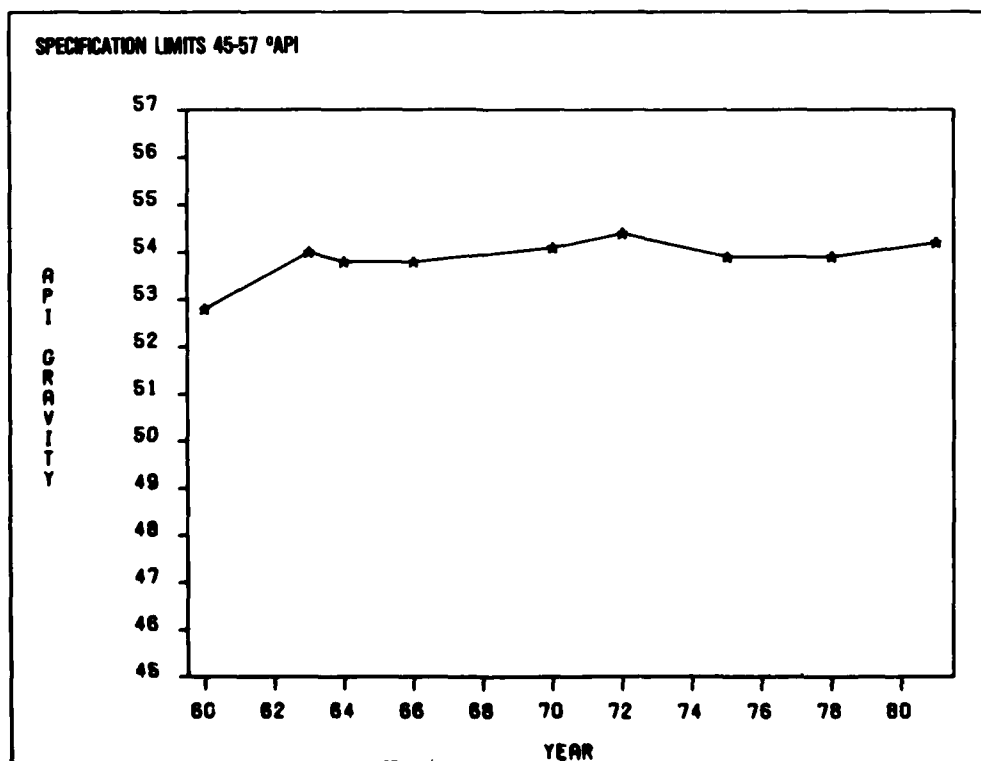


Figure 12. API Gravity Variations from 1960 through 1981

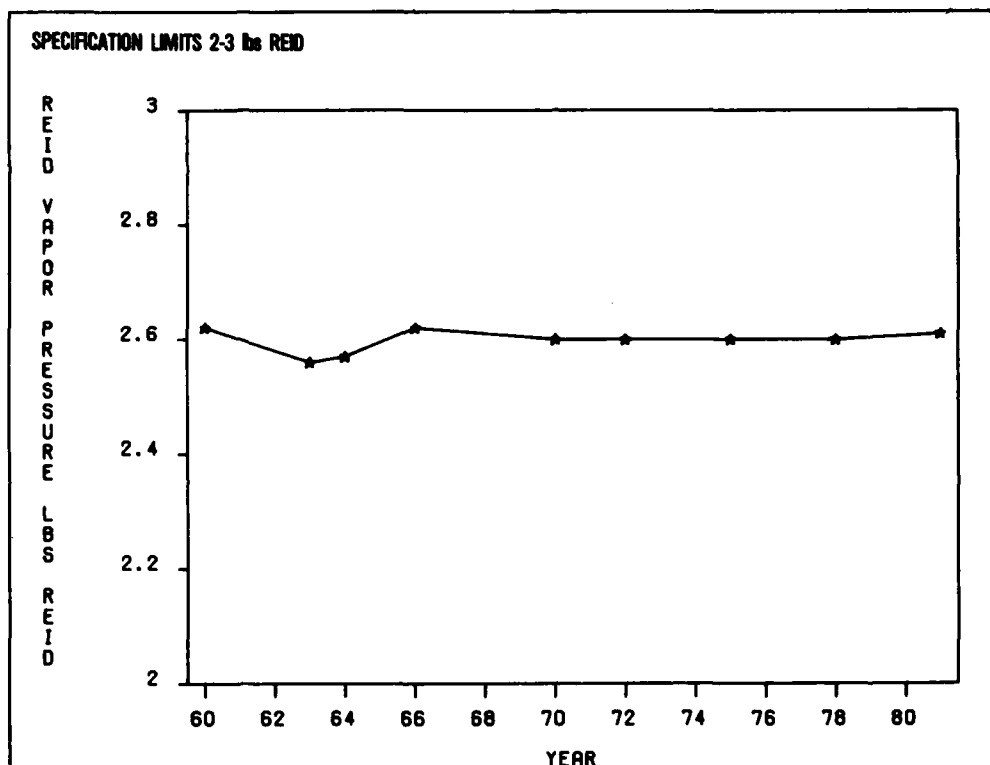


Figure 13. Reid Vapor Pressure Variations from 1960 through 1981

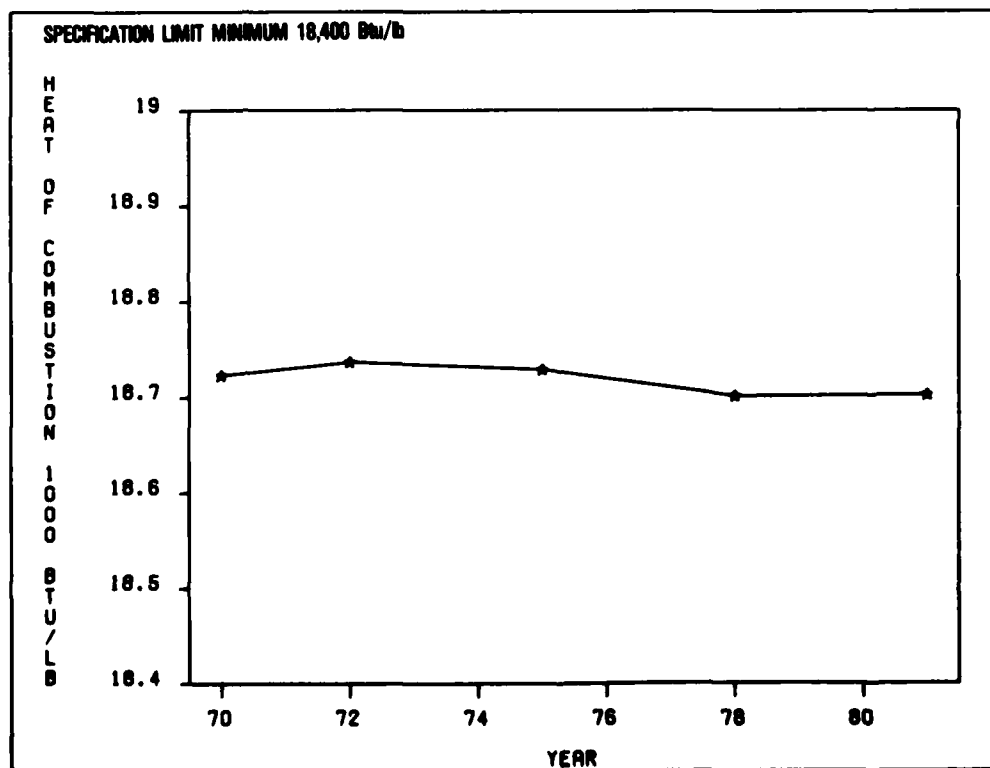


Figure 14. Heat of Combustion Variations from 1970 through 1981

10. SMOKE POINT

Figure 15 illustrates the trends in smoke point from 1960 through 1981. A value was listed in 1960 but no additional data were available until 1972. From 1972 through 1981 the smoke point has decreased, indicating a decrease in combustion performance.

11. THERMAL STABILITY

Figure 16 illustrates the trends in thermal stability pressure drop from 1963 through 1981. There is a large change in pressure drop in 1978 because in 1976 the Coker method (ASTM D 1660 Standard) for measuring thermal stability was replaced by the Jet Fuel Thermal Oxidation Tester (ASTM D 3241 JFTOT) method of determining thermal stability. With this change in test method, the size filter employed and the fuel flow rates through the filter were changed; thus, the pressure drop baseline was changed. The tube deposit code has remained at a level of one or less since the beginning of the use of the JFTOT.

12. EXISTENT GUM

Figure 17 illustrates the trends in existent gum from 1960 through 1981. Over the 21 years, there has been little variation in gum with a value of approximately 1mg/100ml.

13. PARTICULATE MATTER

Figure 18 illustrates the variations in particulate matter from 1970 through 1981. In 1972, the specification was changed from 4mg/gal to 1mg/l. Since 1972, there has been little variation in particulate matter with a relatively constant value of 0.4 mg/l.

14. WSIM

Figure 19 illustrates the variations in WSIM from 1970 through 1981. There has been little variation in WSIM over the 11 years with an approximately constant value of 90.

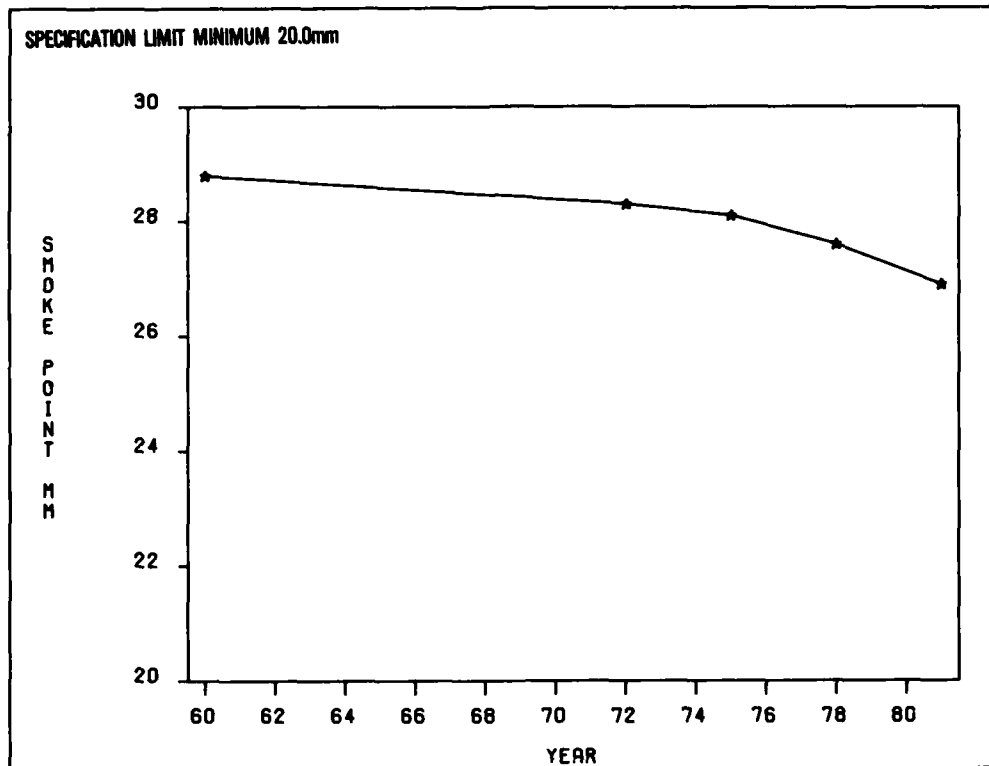


Figure 15. Smoke Point Variations from 1960 through 1981

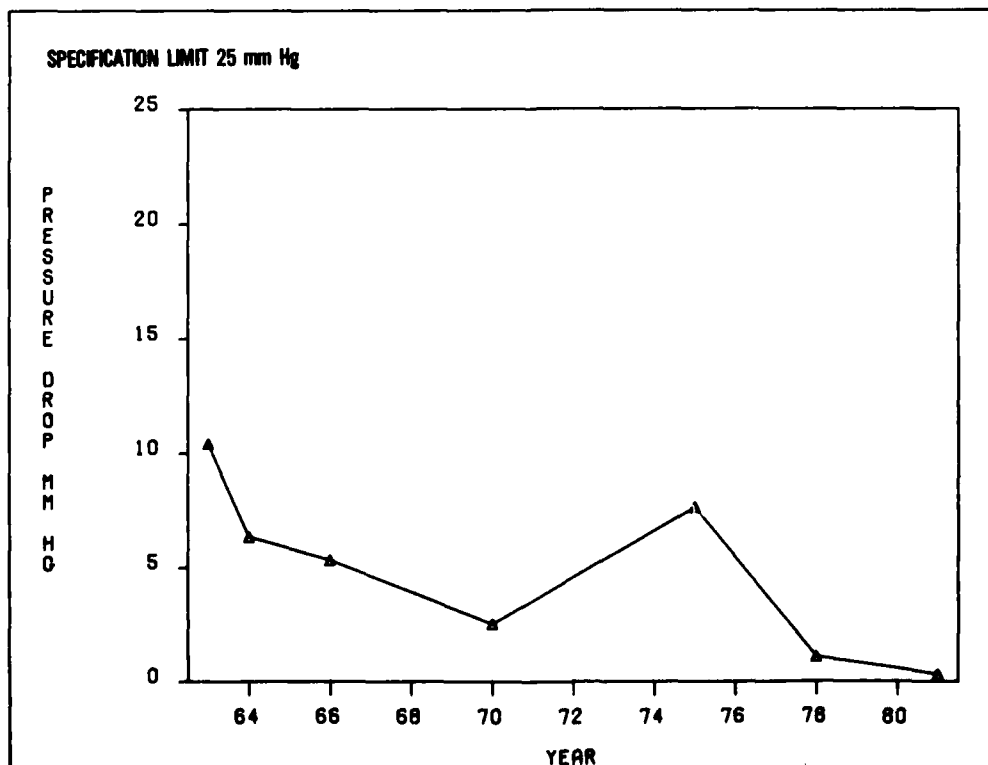


Figure 16. Thermal Stability Pressure Drop Variations from 1963 through 1981

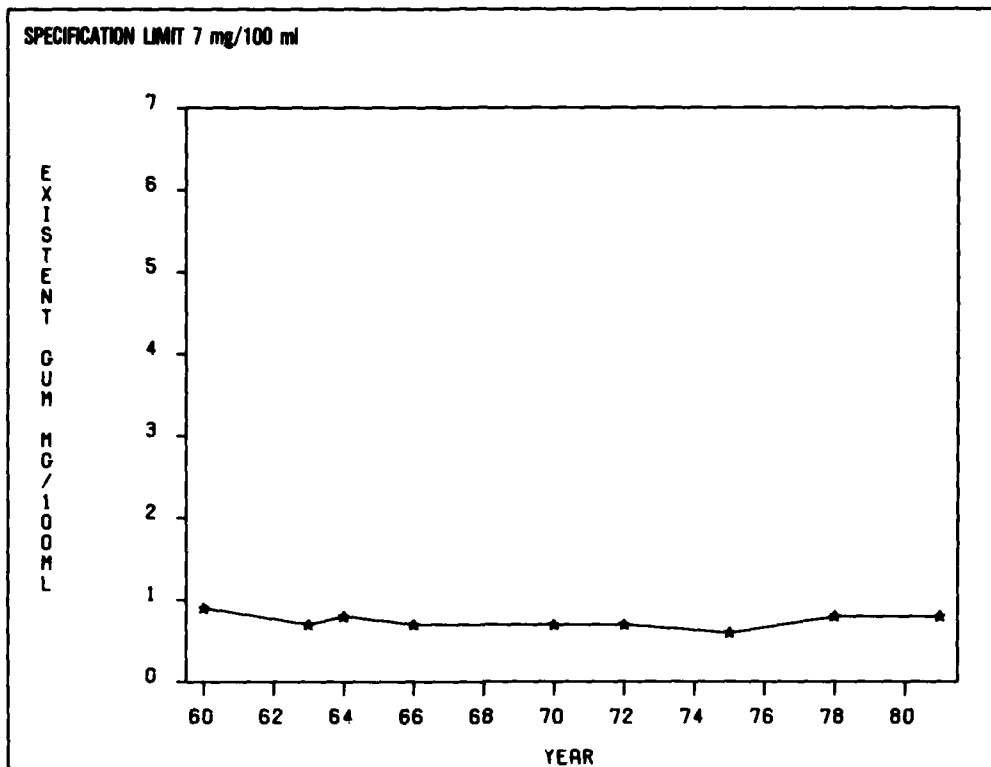


Figure 17. Existant Gum Variations from 1960 through 1981

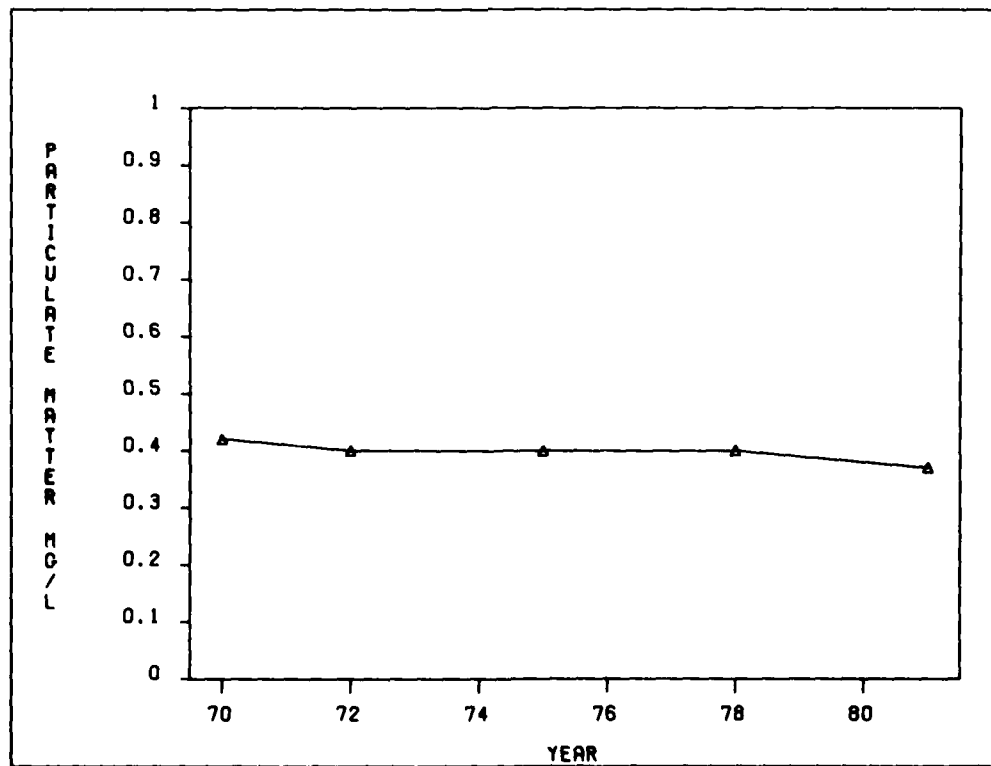


Figure 18. Particulate Matter Variations from 1970 through 1981

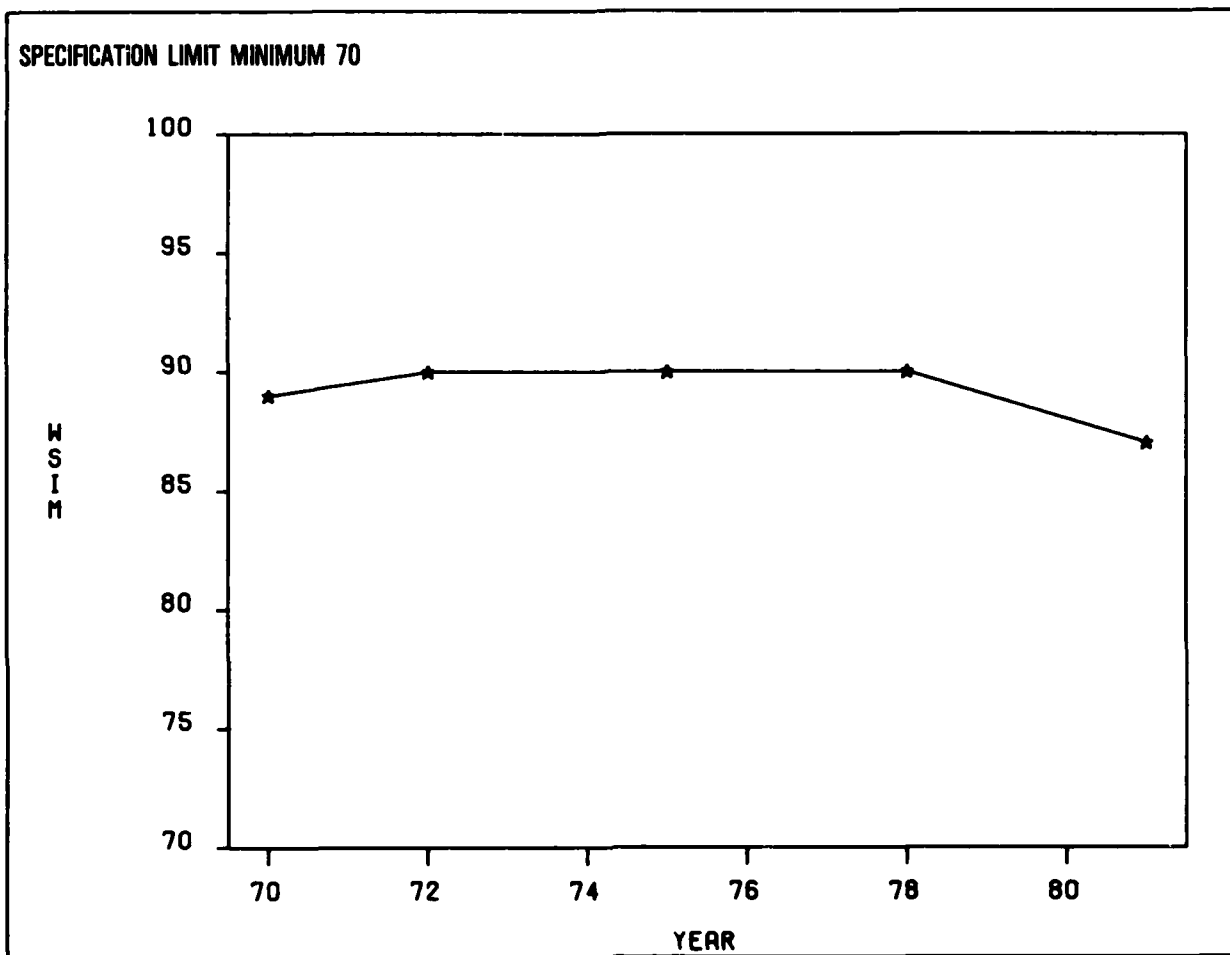


Figure 19. WSIM Variations from 1970 through 1981

SECTION V

THE CHEMICAL AND PHYSICAL PROPERTIES OF JP-4

This section of the report summarizes the chemical and physical properties of JP-4 for the period July 1980 through 1981. The data are presented as histograms. Each section describes a specific property by 1) a histogram of the "average" property worldwide, 2) histograms subdividing the worldwide data into eight districts, and 3) a summary of the properties from individual states for districts 1 through 5. The final section discusses possible seasonal variations in JP-4 due to the seasonal variations in the production of gasoline and home heating oil.

The eight districts are classified in Table 8. Districts 1 through 5 are classified in the same manner as those by the Petroleum Administration for Defense. The states and regions that comprise the districts are identified in Table 9.

TABLE 8

GEOGRAPHICAL DISTRICTS

1. East Coast
2. Midwest
3. South
4. Rocky Mountain
5. Pacific
6. Far East
7. Europe and Near East
8. South America, West Indies, Canada

TABLE 9
GEOGRAPHICAL DISTRICTS

<u>District 1</u> <u>East Coast</u>	<u>District 2</u> <u>Midwest</u>	<u>District 3</u> <u>South</u>	<u>District 4</u> <u>Rocky Mountain</u>	<u>District 5</u> <u>Pacific</u>	<u>District 6</u> <u>Far East</u>
Connecticut	Illinois	Alabama	Colorado	Arizona	Guam
Delaware	Indiana	Arkansas	Idaho	California	Singapore
District of Col.	Iowa	Louisiana	Montana	Nevada	Japan
Florida	Kansas	Mississippi	Utah	Oregon	
Georgia	Kentucky	New Mexico	Wyoming	Washington	
Maine	Michigan	Texas		Alaska	
Maryland	Minnesota			Hawaii	
Massachusetts	Missouri				
New Hampshire	Nebraska				
New Jersey	North Dakota			<u>District 8</u>	
New York	Ohio	Europe		South America	
North Carolina	Oklahoma	Near East		West Indies	
Pennsylvania	South Dakota	Africa		Canada	
Rhode Island	Tennessee			Virgin Islands	
South Carolina	Wisconsin				
Vermont					
West Virginia					
Virginia					

1. TOTAL ACID NUMBER

The total acid number of JP-4 varies worldwide from 0.000 to the specification limit of 0.015 mg KOH/g. A large variation was shown from district to district, also from state to state within the Continental United States (CONUS), including Hawaii. The "average" total acid number worldwide was 0.005 mg KOH/g. Within the CONUS, fuels from Tennessee had the lowest average total acid number of 0.001; fuels from Louisiana had the highest average total acid number of 0.012 mg KOH/g. The "near specification limit" for this test was 0.010. Approximately eight percent of the fuel lots fell within this "near specification band."

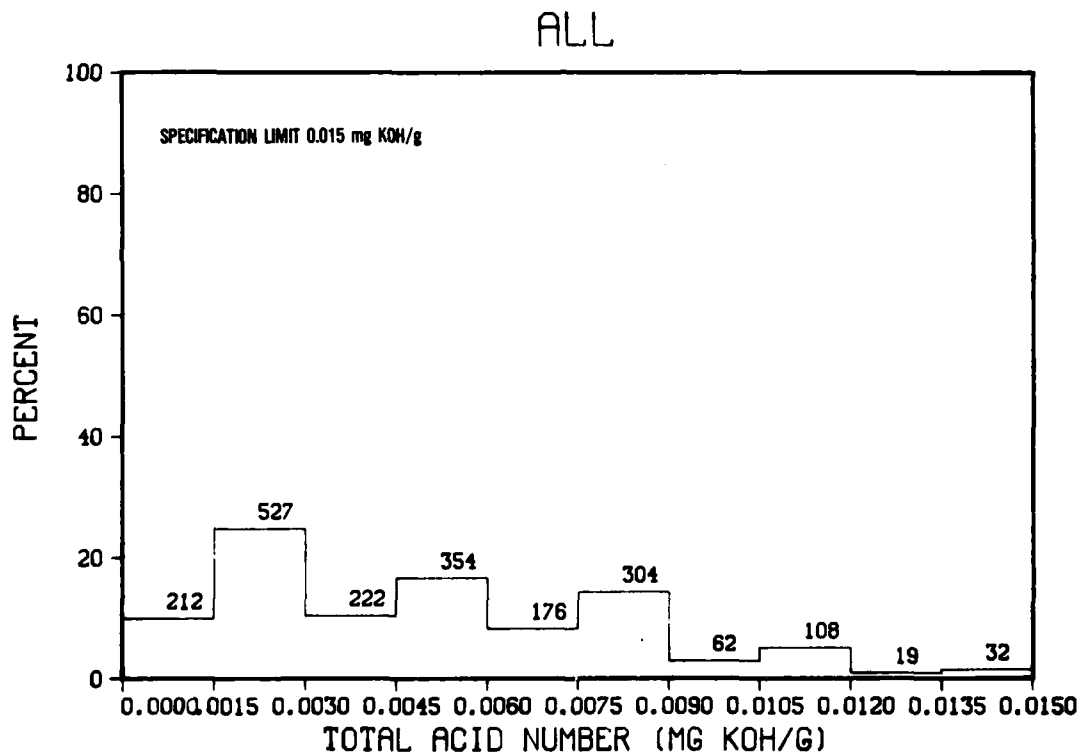


Figure 20. Total Acid Number Variations: Worldwide

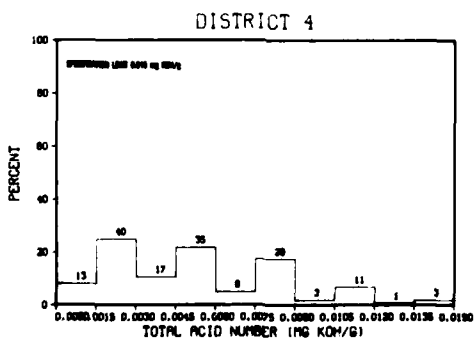
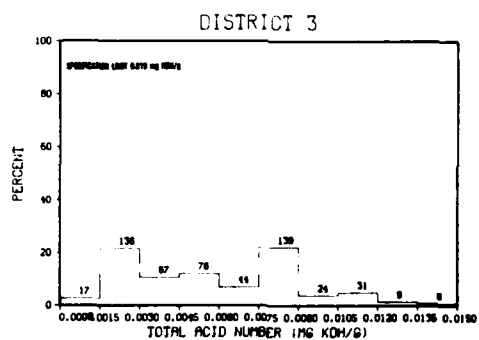
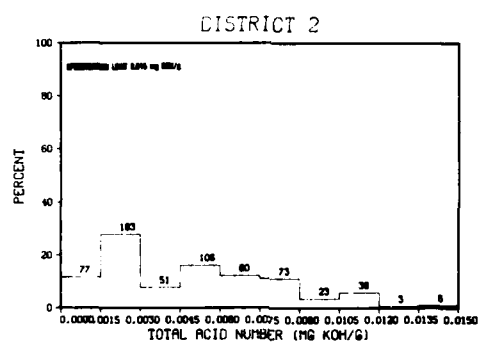
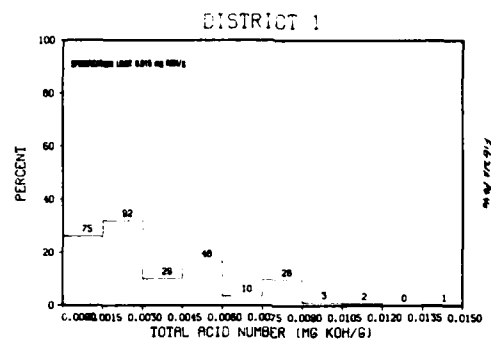


Figure 21. (a-d) Total Acid Number Variations: Districts 1 - 4

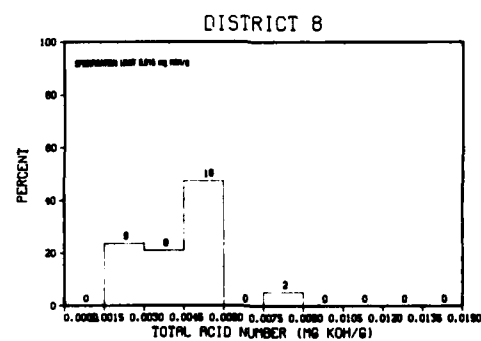
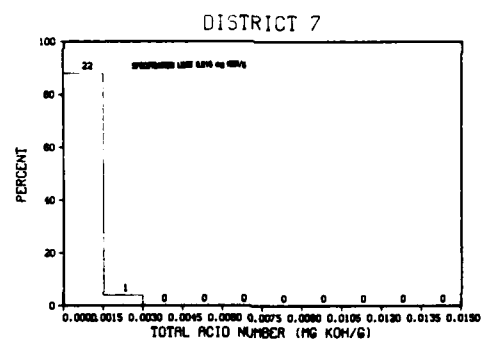
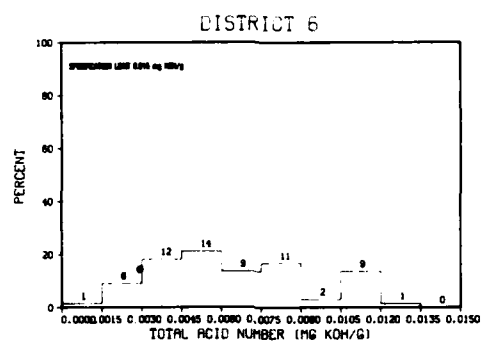
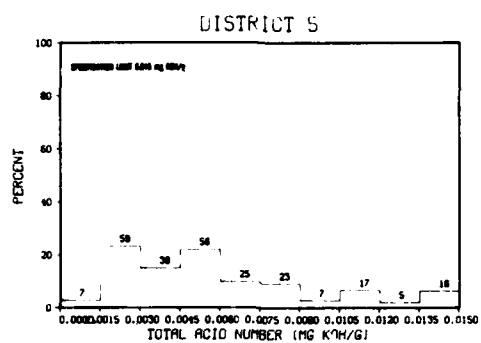


Figure 21 Continued (e-h) Total Acid Number Variations: Districts 5 - 8

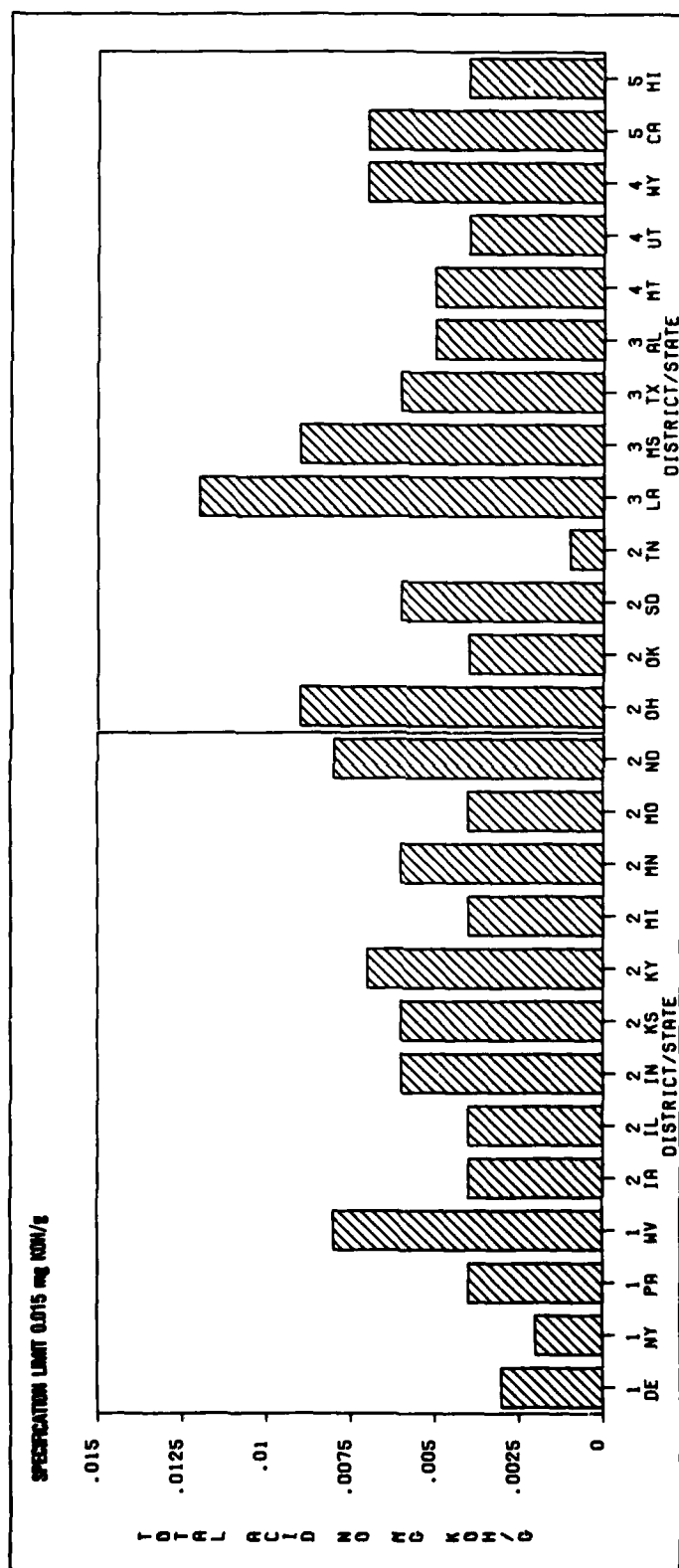


Figure 22. Total Acid Number Variations: States

2. VOLUME PERCENT AROMATICS

The volume percent aromatics in JP-4 varies worldwide from 0.0 to the specification limit of 25.0 volume percent. Variation existed from district to district, and also from state to state within the CONUS. The "average" volume percent aromatics worldwide was 12.6 percent. Within the United States, fuels from Kansas had the lowest average volume percent aromatics of 6.2; fuels from North Dakota had the highest average volume percent aromatics of 20.0 percent. The "near specification value" for this test was 21.5 volume percent. Approximately 4 percent of the fuel lots fell in this "near specification band."

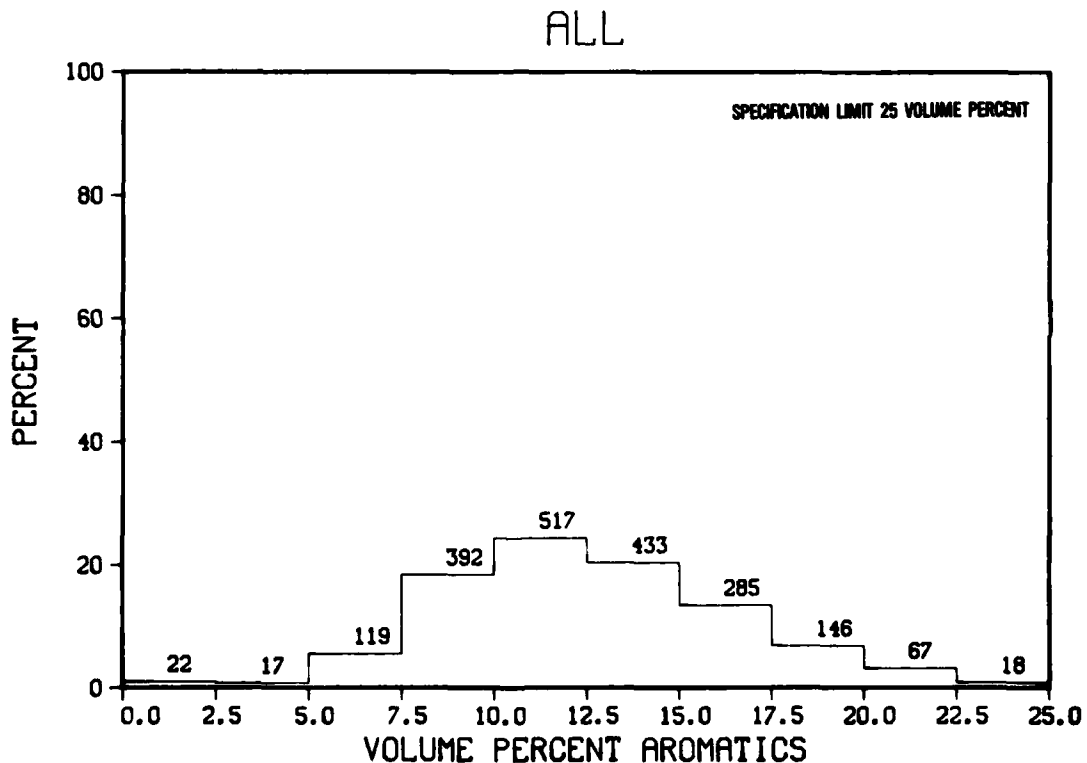


Figure 23. Volume Percent Aromatics Variations: Worldwide

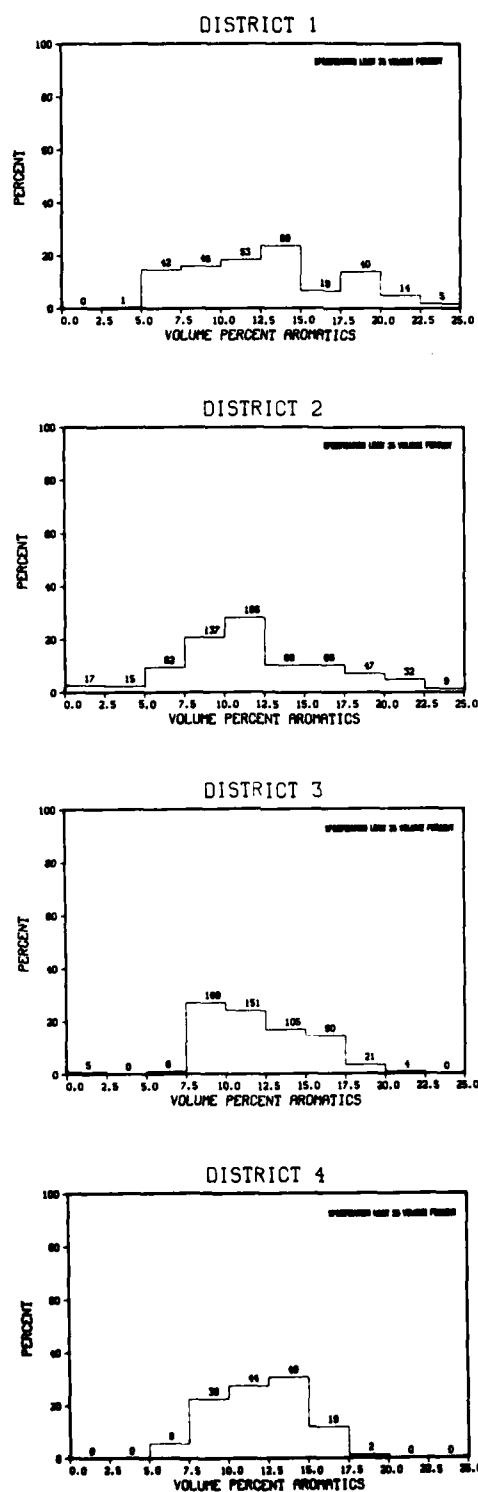


Figure 24. (a-d) Volume Percent Aromatics Variations: Districts 1 - 4

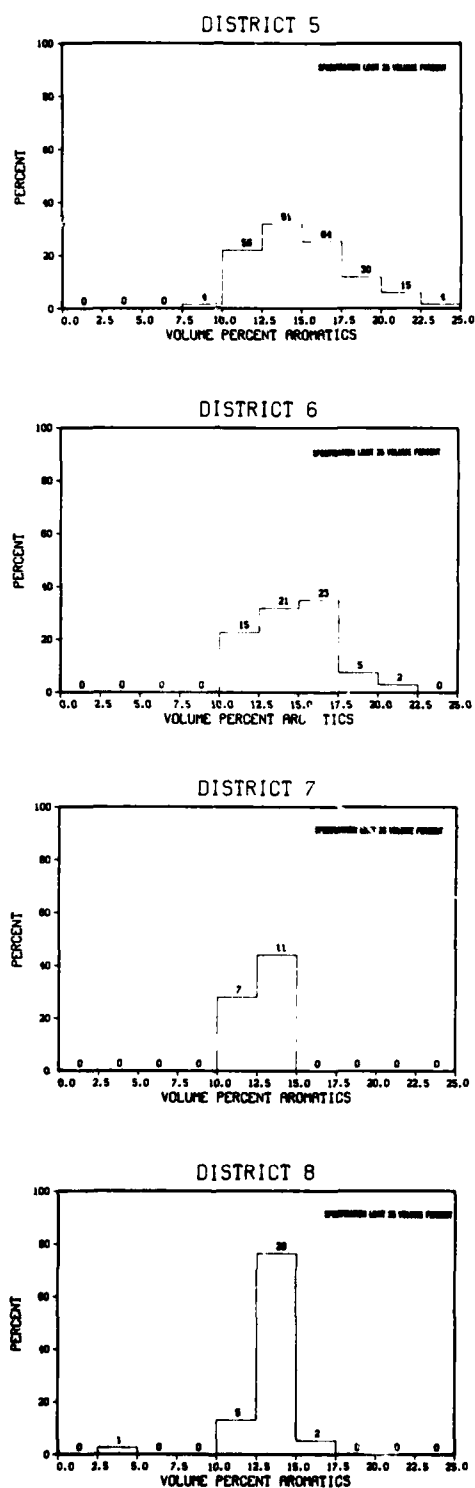
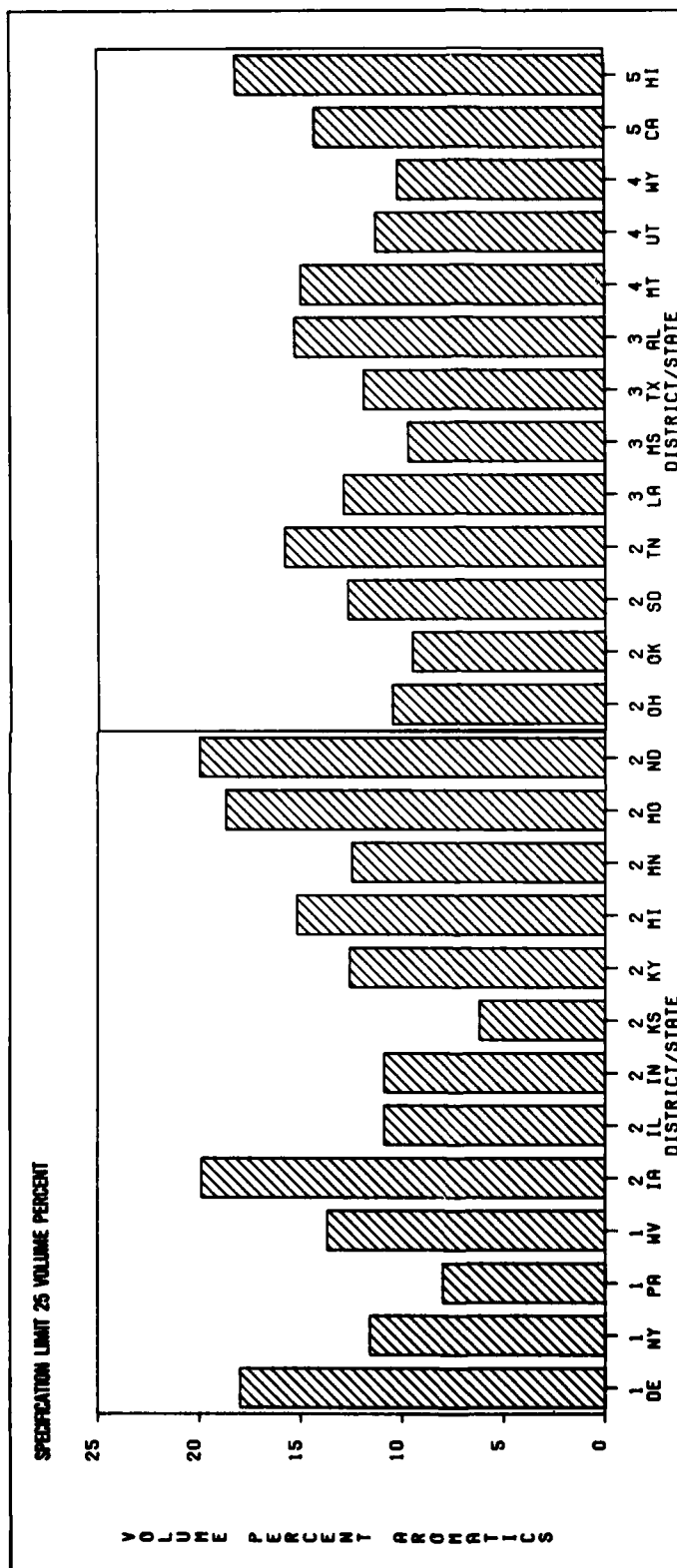


Figure 24. Continued (e-h) Volume Percent Aromatics Variations: Districts 5-8



Volume 25. Volume Percent Aromatics Variations: States

3. VOLUME PERCENT OLEFINS

The volume percent olefins in JP-4 varies worldwide from 0.0 to 4.5 volume percent, with all values below the specification requirement of 5.0 volume percent. Variations existed among districts worldwide with very few values above 2.0 volume percent. The "average" volume percent olefins worldwide was 0.8 volume percent. Within the United States, Michigan, Minnesota, Missouri, and South Dakota had the lowest "average" percent olefins, 0.4 volume percent; fuels from North Dakota had the highest "average" volume percent olefins, 1.6 volume percent. The "near specification value" for this test was 1.7 volume percent. Approximately five percent of the fuel lots fell in this "near specification band."

ALL

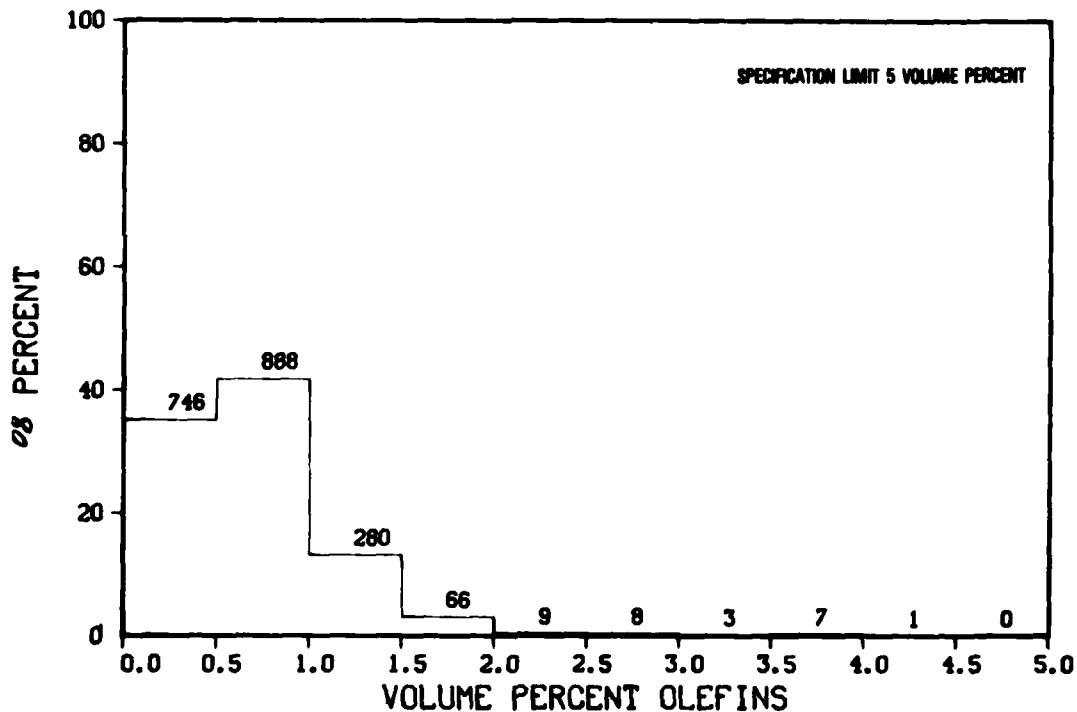


Figure 26. Volume Percent Olefins Variations: Worldwide

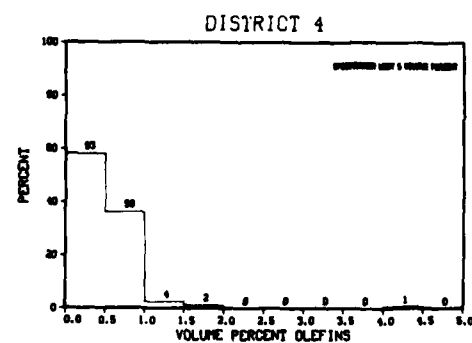
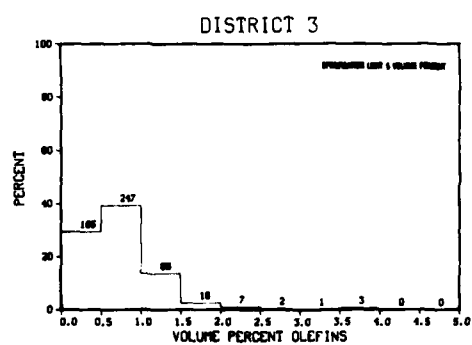
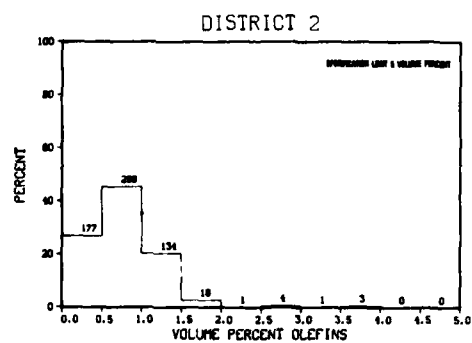
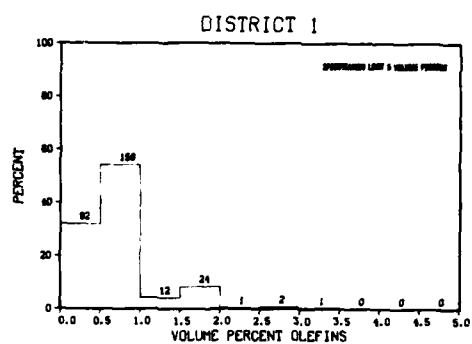


Figure 27. (a-d) Volume Percent Olefins Variations: Districts 1 - 4

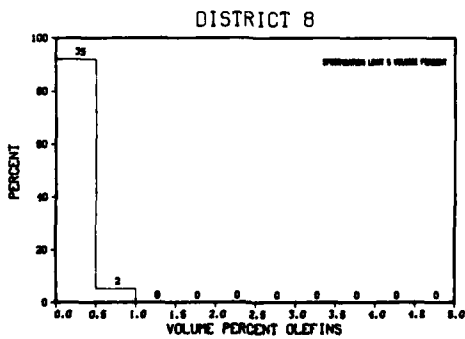
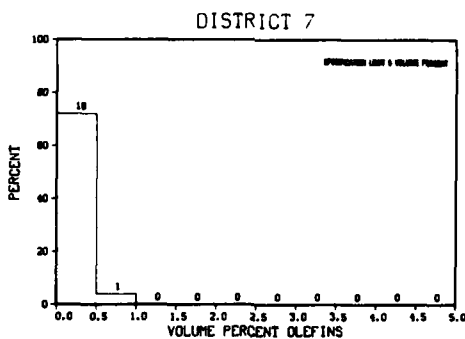
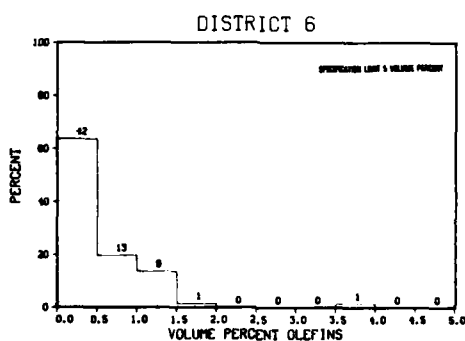
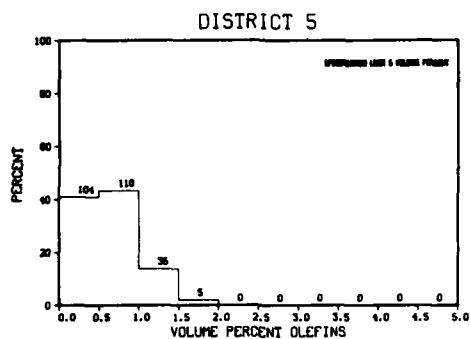


Figure 27. Continued (e-h) Volume Percent Olefins Variations:
Districts 5 - 8

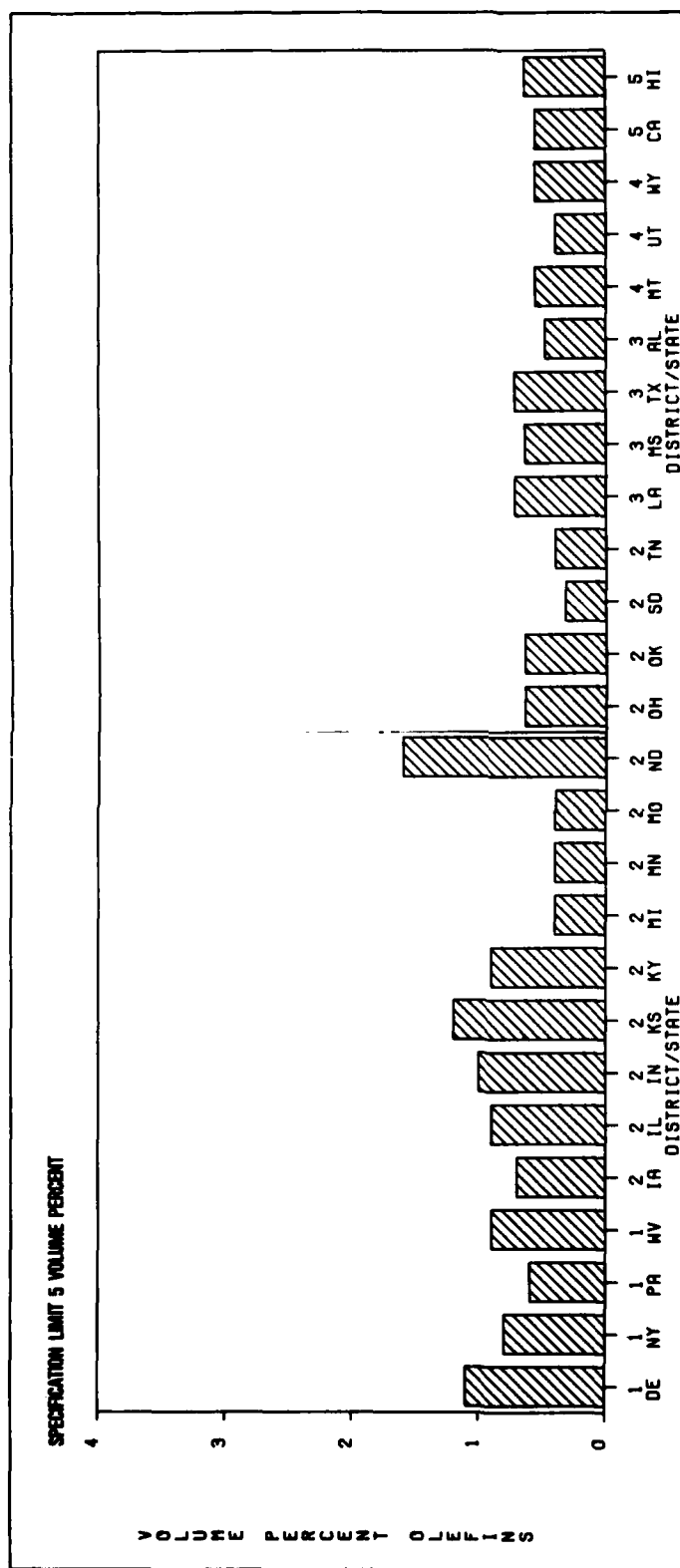


Figure 28. Volume Percent Olefins Variations: States

4. MERCAPTAN SULFUR

The weight percent mercaptan sulfur in JP-4 varies worldwide from 0.000 to the specification limit of 0.001 weight percent mercaptan sulfur. Variations existed among districts worldwide and among states within the CONUS. District 7 reported no samples with this test run. It should be noted that refiners may determine weight percent mercaptan sulfur or use the doctor test. The average weight percent mercaptan sulfur worldwide was 0.0004 weight percent. Within the CONUS, Indiana, Kentucky, Ohio and Montana had fuels with 0.000 weight percent mercaptan sulfur. West Virginia's fuels were analyzed with the weight percent mercaptan sulfur at or above the specification limits of 0.001 weight percent. The "near specification value" for this test was 0.0006 weight percent mercaptan sulfur. Approximately 20 percent of the fuel lots fell within this "near specification band." It should be noted that fuels that have a high mercaptan sulfur result but were doctor tested "sweet" were accepted as specification fuels.

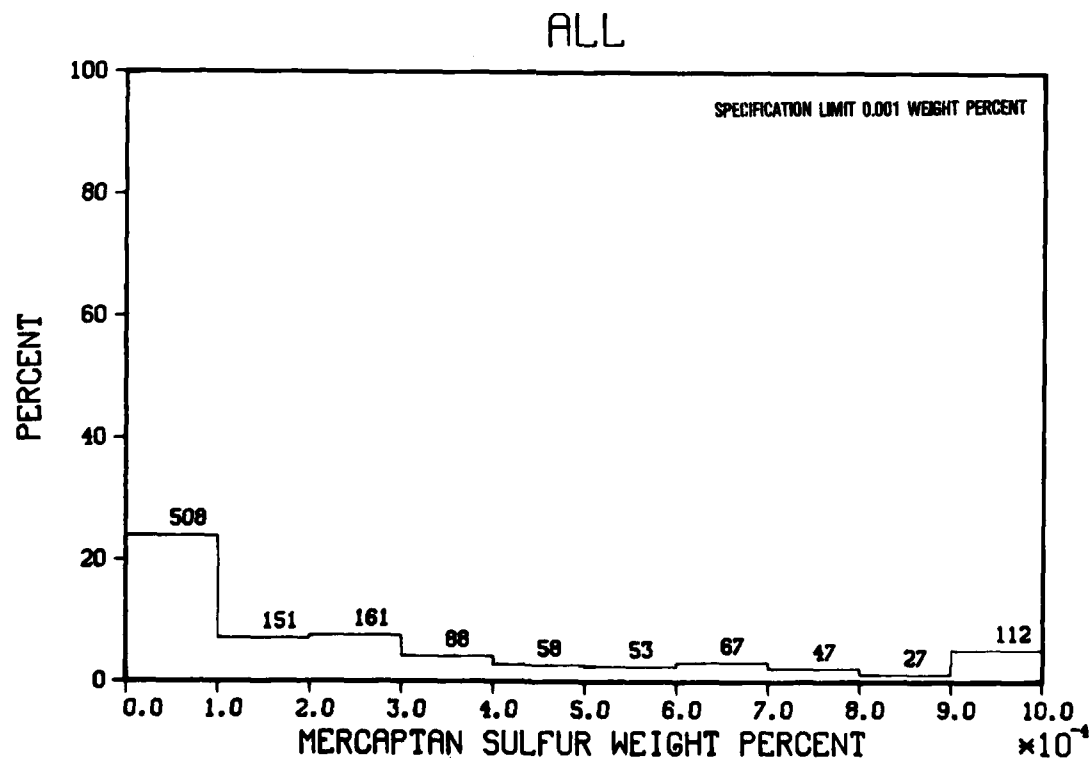


Figure 29. Weight Percent Mercaptain Sulfur Variations: Worldwide

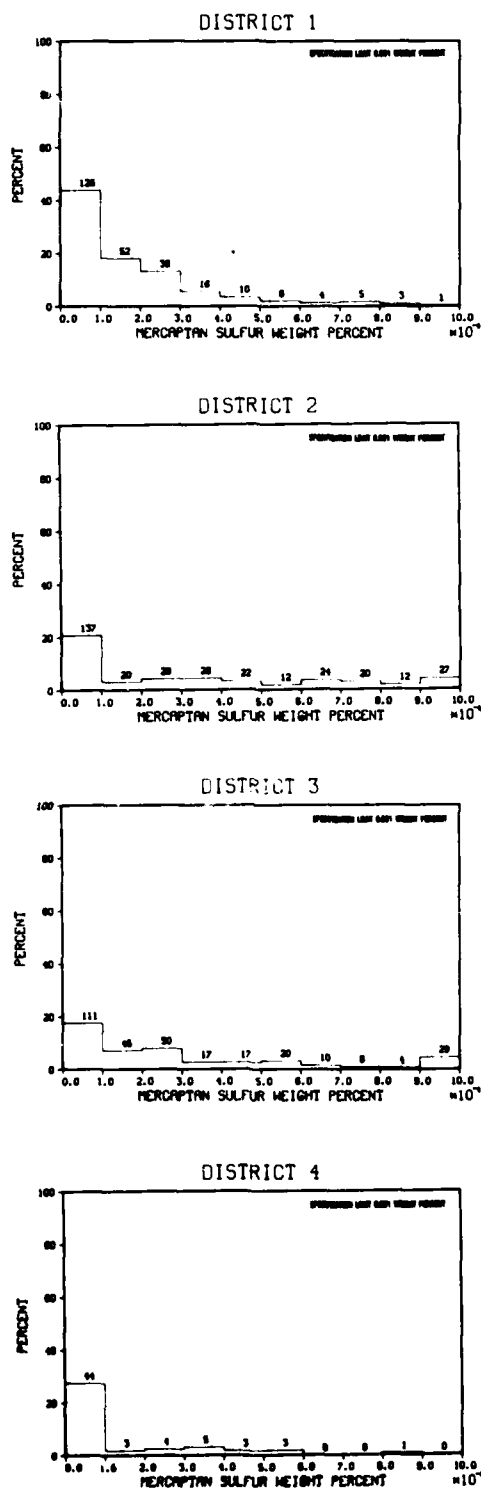


Figure 30. (a-d) Weight Percent Mercaptan Sulfur Variations: Districts 1 - 4

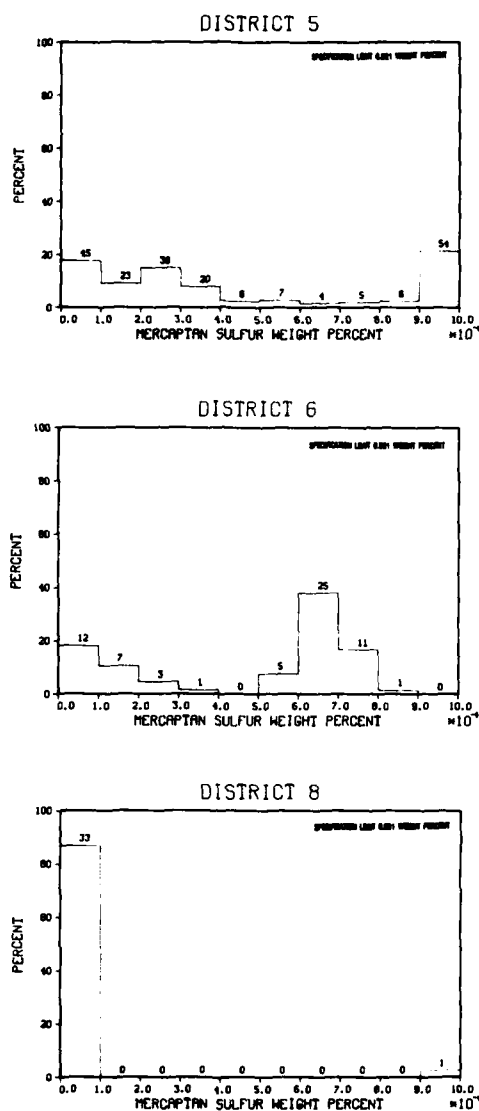


Figure 30. Continued (e-g) Weight Percent Mercaptan Sulfur Variations: Districts 5, 6, and 8

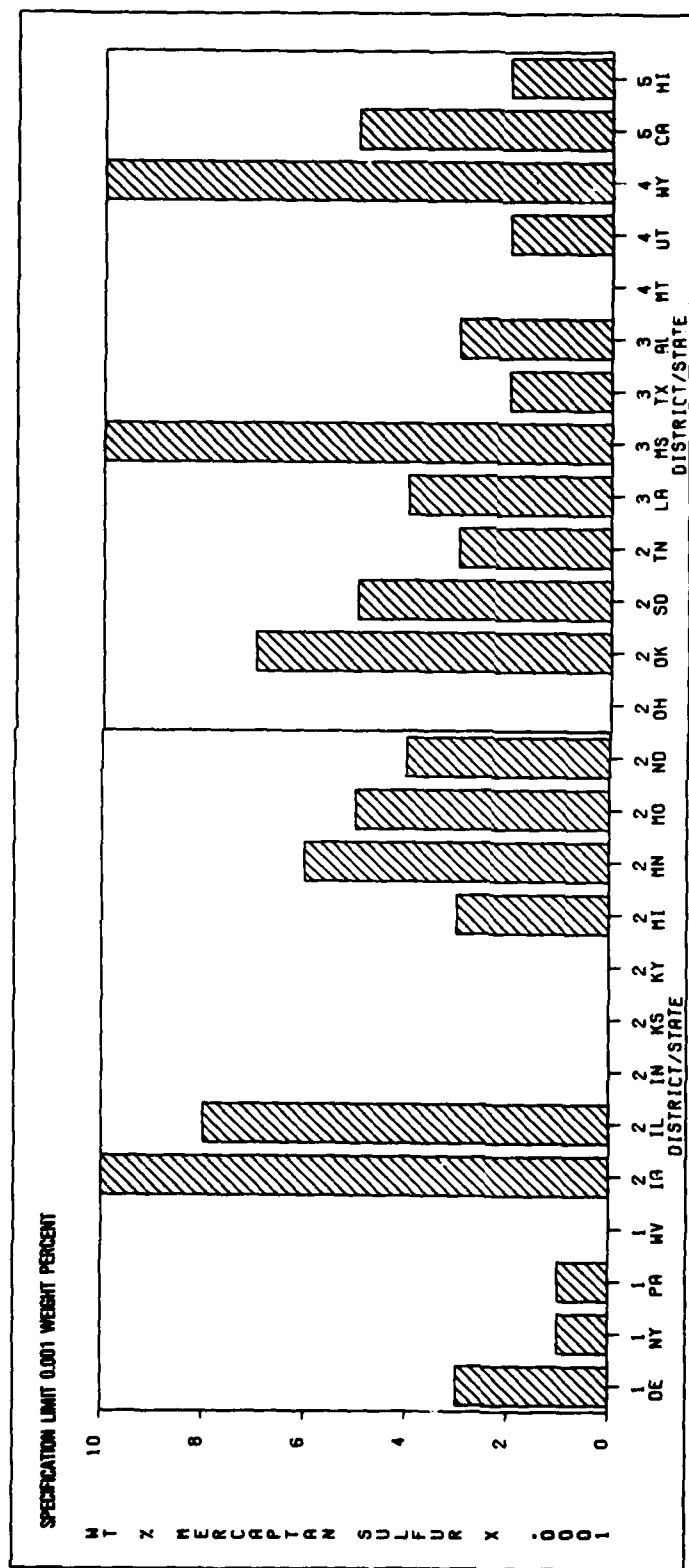


Figure 31. Weight Percent Mercaptan Sulfur Variations: States

5. TOTAL SULFUR

The total sulfur in JP-4 varies from 0.0 to the specification limit of 0.4 weight percent sulfur. Variations existed from district to district with most of the values less than 0.2 weight percent sulfur. The average weight percent total sulfur worldwide is 0.04 weight percent. Within the CONUS, fuels from Illinois, North Dakota, South Dakota, Tennessee, and Wyoming had the lowest "average" weight percent total sulfur of 0.01 weight percent. New York had the highest "average" weight percent total sulfur of 0.15 weight percent. The "near specification value" for this test is 0.34 weight percent sulfur. Less than one percent of the fuel lots fell within this "near specification band."

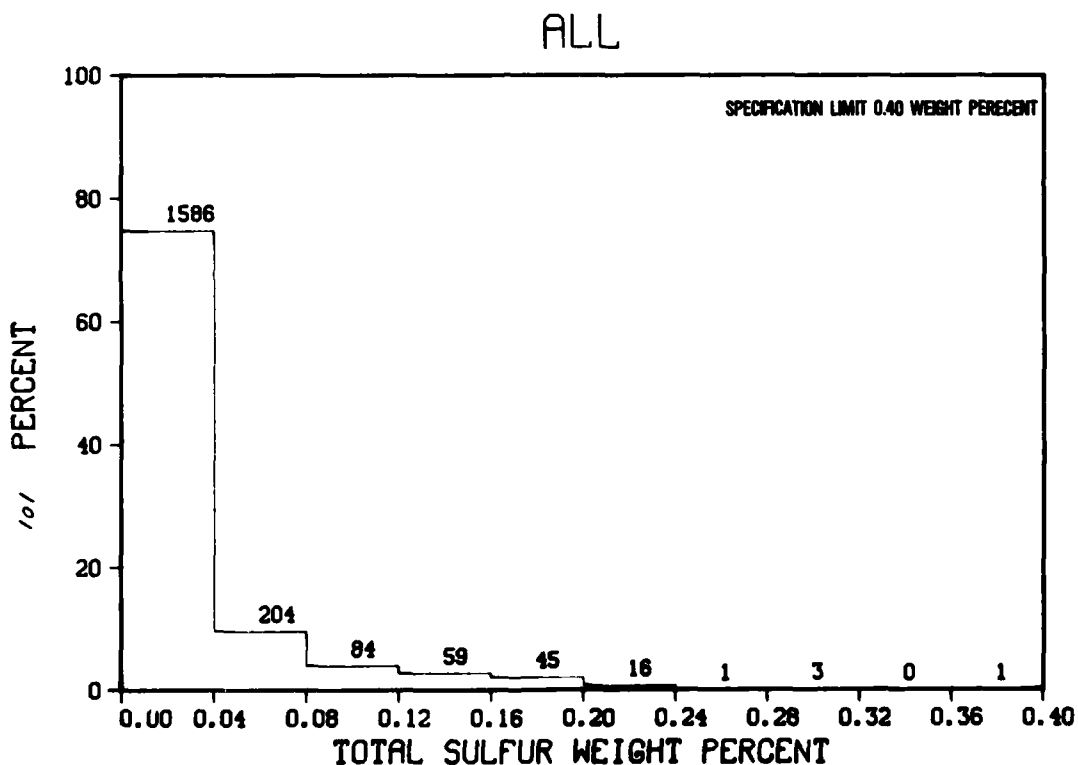


Figure 32. Weight Percent Total Sulfur Variations: Worldwide

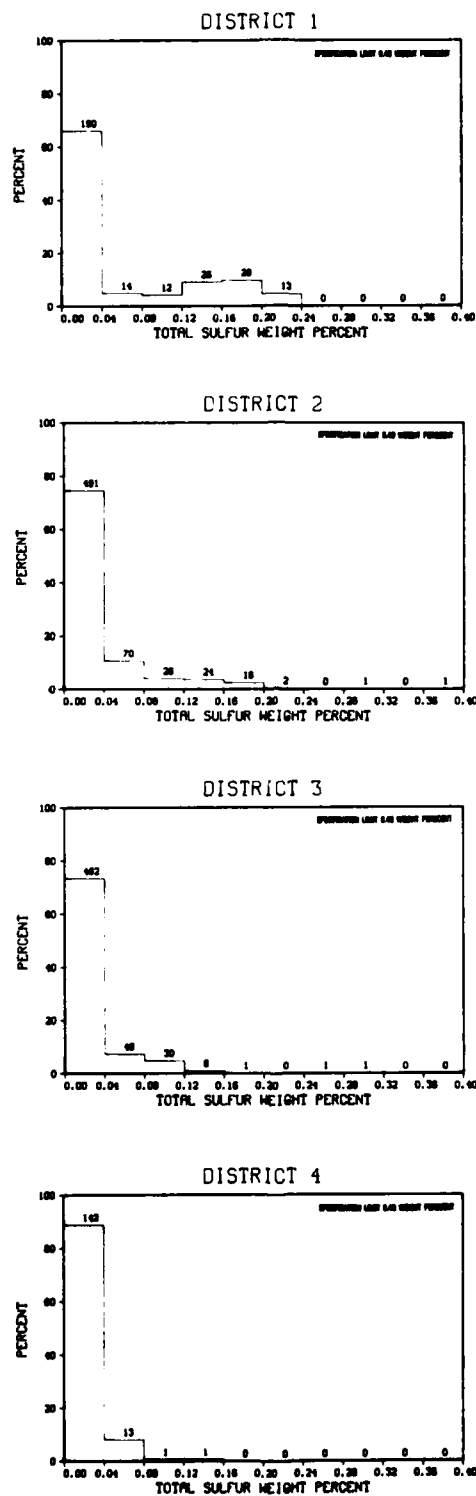


Figure 33. (a-d) Weight Percent Total Sulfur Variations:
Districts 1 - 4

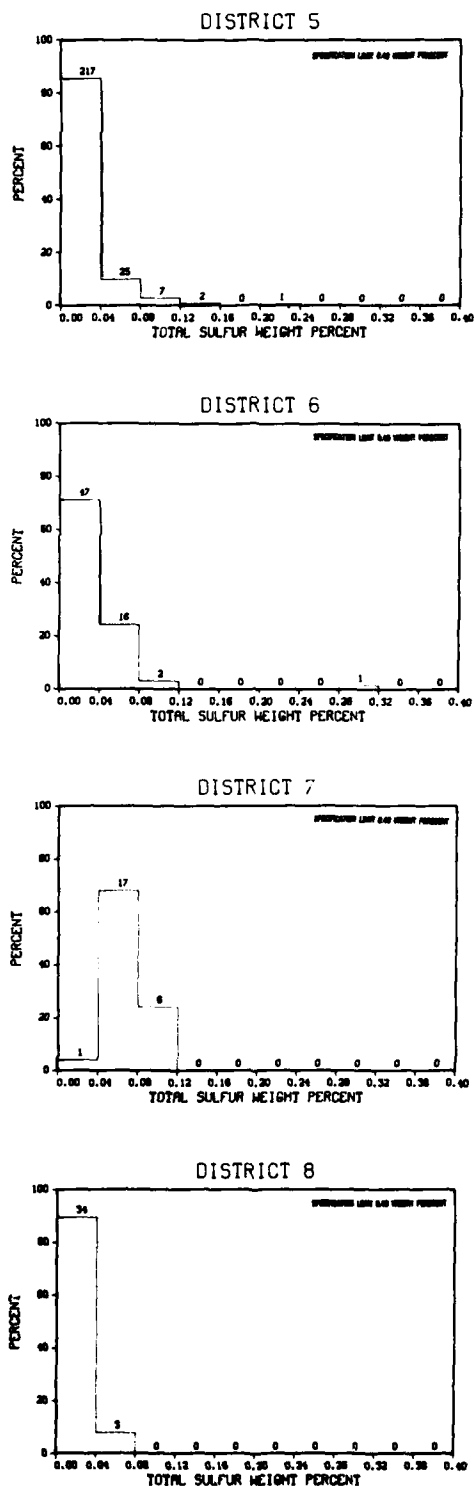


Figure 33. Continued (e-h) Weight Percent Total Sulfur Variations:
Districts 5 - 8

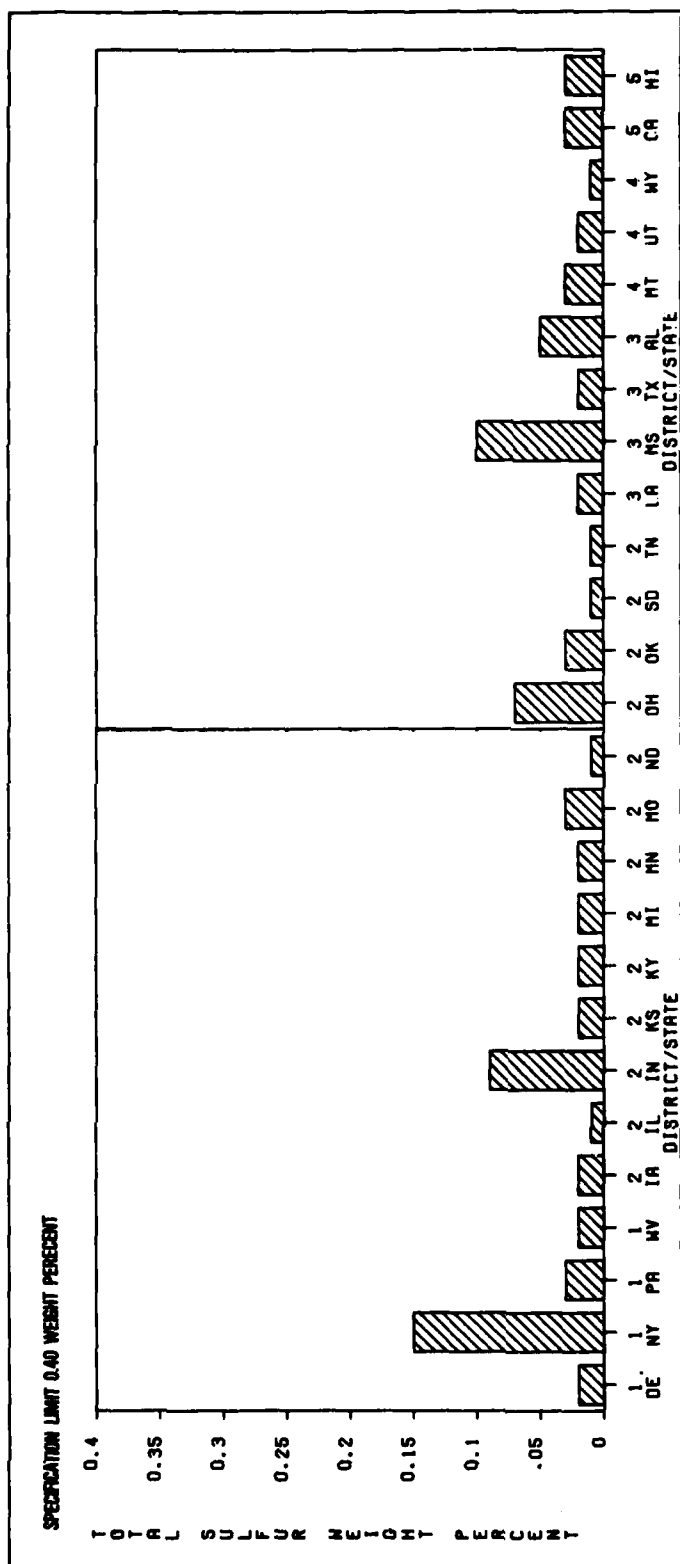


Figure 34. Weight Percent Total Sulfur Variations: States

6. BOILING RANGE DISTRIBUTION

There was a wide variation in boiling range distribution among the districts which comprise the world. Variations existed among individual lots of fuel within the districts. Generally a fuel with a high 90 percent recovered temperature and a high end point temperature also had a low initial, 10 percent and 20 percent recovered temperature so that the freeze point requirements would be met. A wide variety of refiners' conditions, crude sources, and blending schemes can be inferred from these data. The "average" values for the boiling range distribution worldwide as determined by D 86 distillation were as follows:

Initial boiling point 61°C
 10 Percent recovered 94°C
 20 Percent recovered 107°C
 50 Percent recovered 143°C
 90 Percent recovered 205°C
 Final Boiling point 238°C

ALL

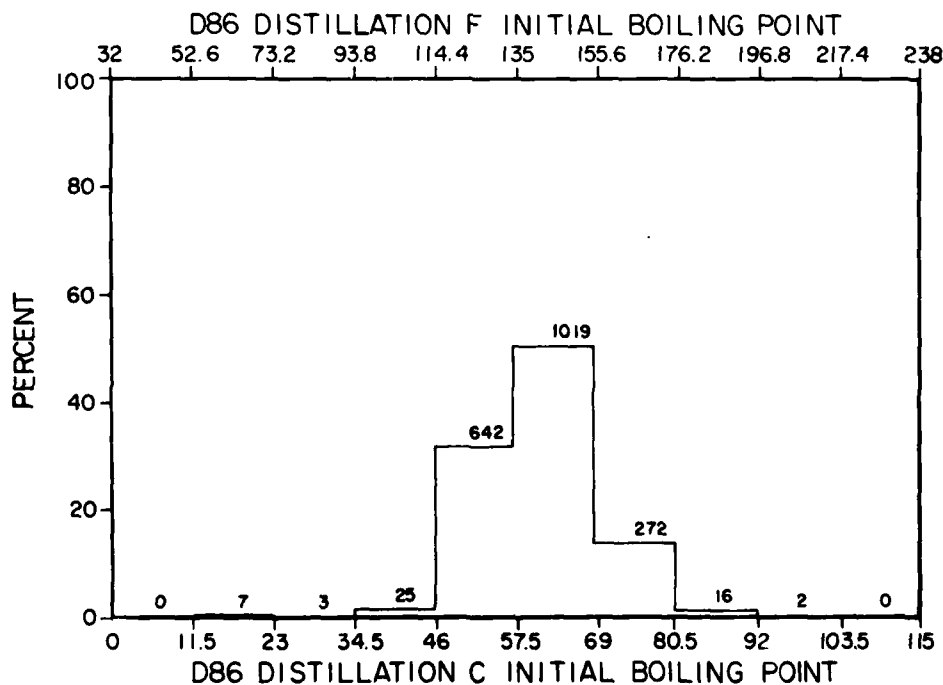


Figure 35. D 86 Distillation Initial Boiling Point Variations: Worldwide

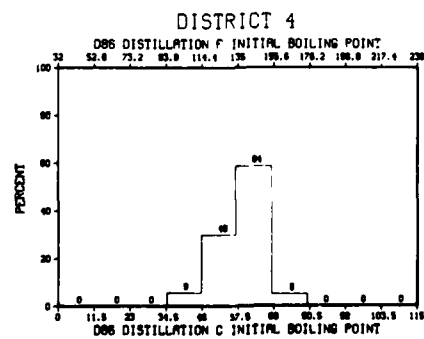
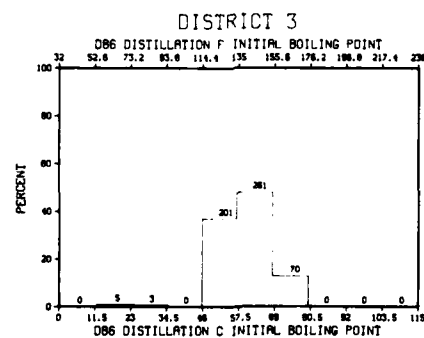
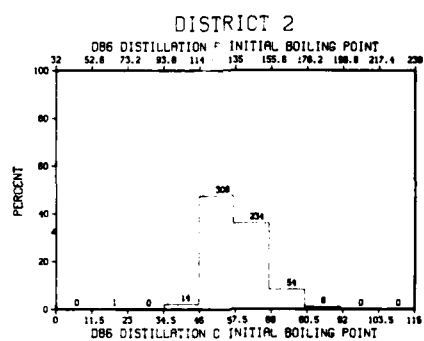
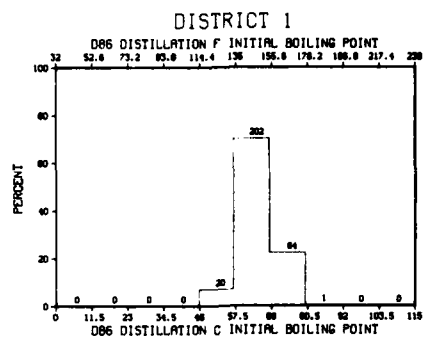


Figure 36. (a-d) D 86 Distillation Initial Boiling Point Variations:
Districts 1 - 4

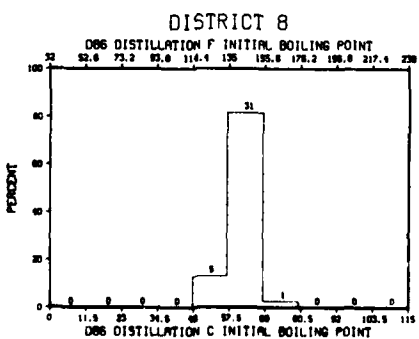
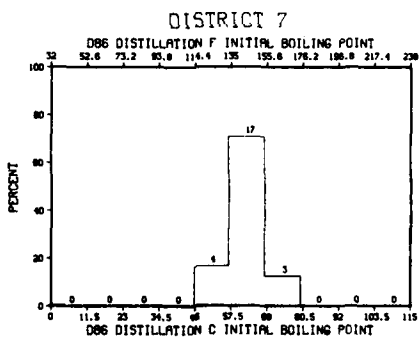
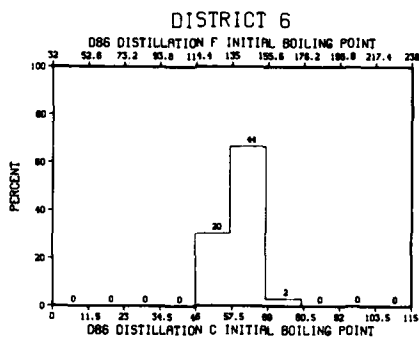
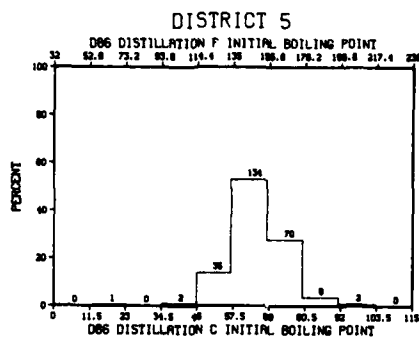


Figure 36. Continued (e-h) D 86 Distillation Initial Boiling Point Variations: Districts 5 - 8

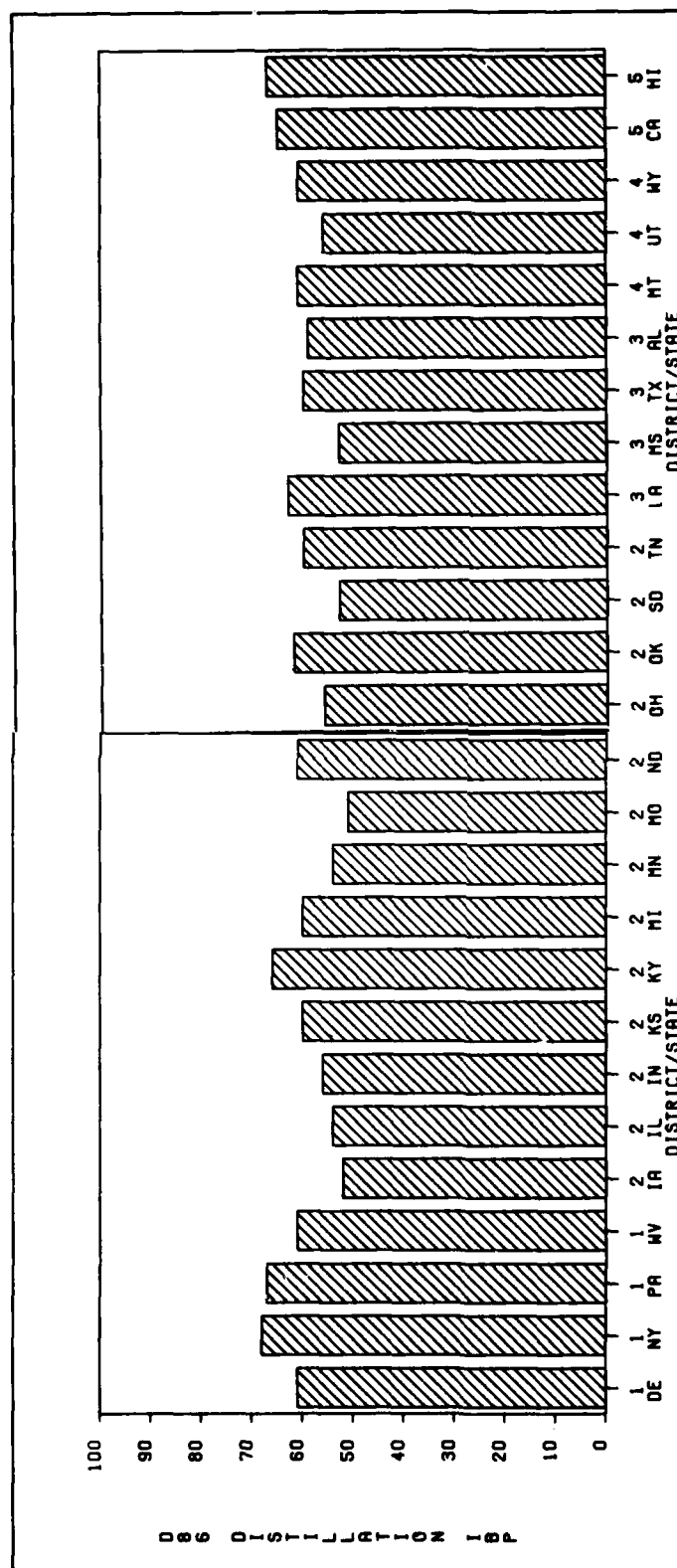


Figure 37. D 86 Distillation Initial Boiling Point Variations: States

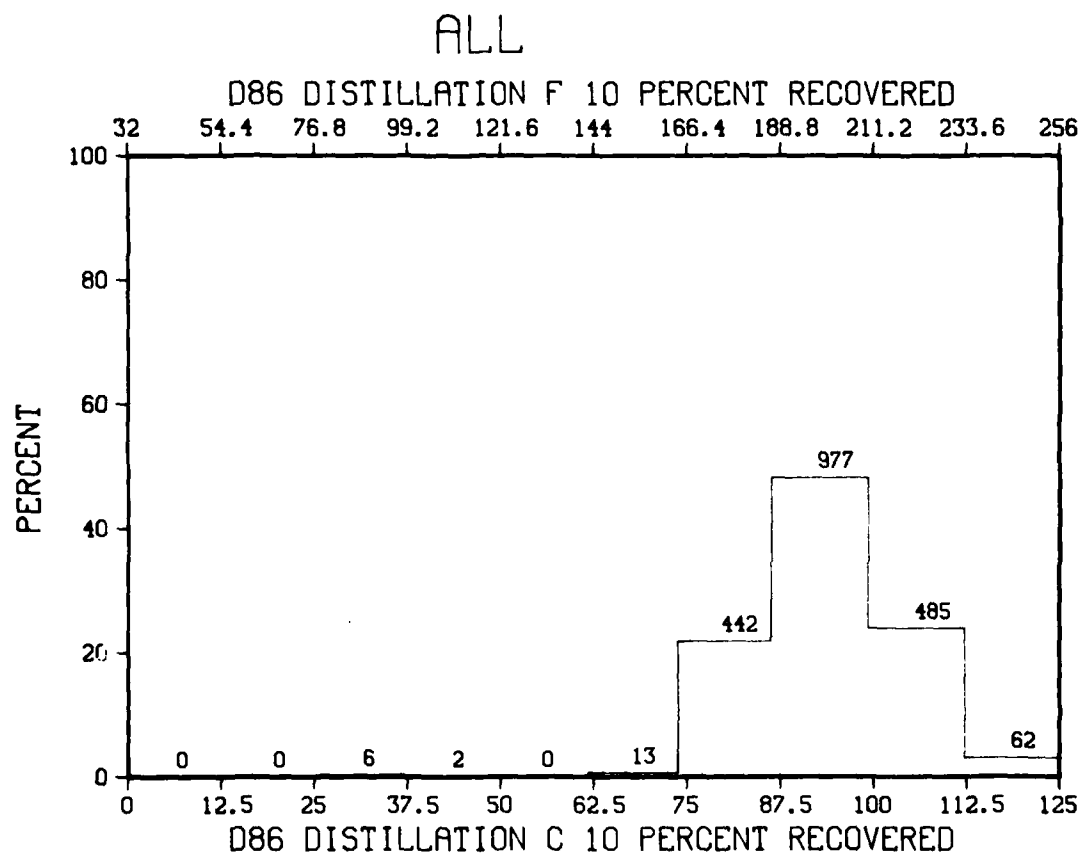


Figure 38. D 86 Distillation 10% Recovered Variations: Worldwide

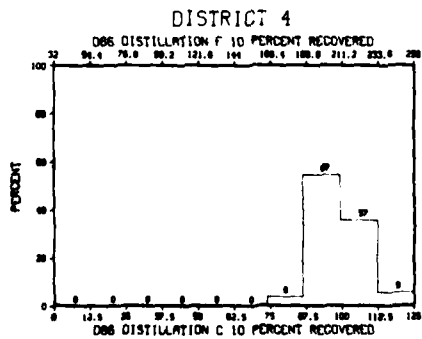
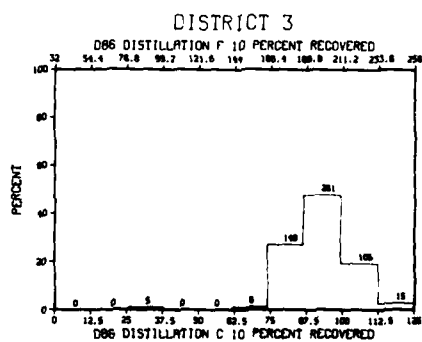
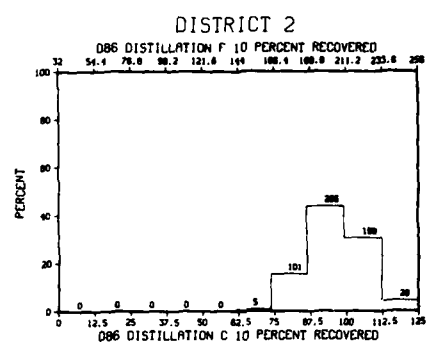
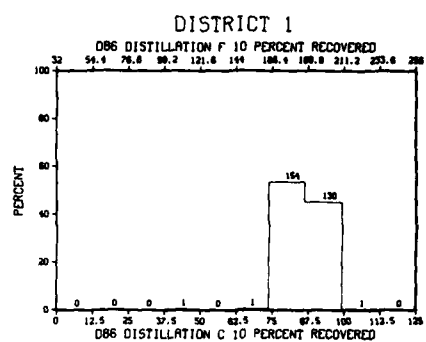


Figure 39. (a-d) D 86 Distillation 10% Recovered Variations:
Districts 1 - 4

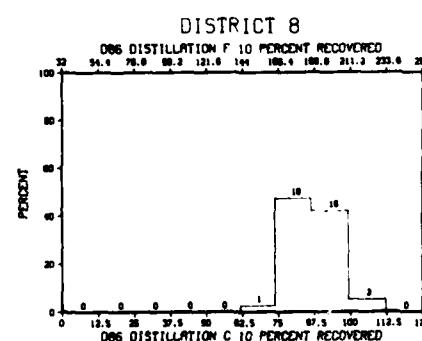
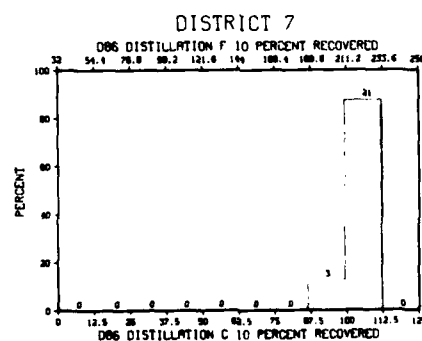
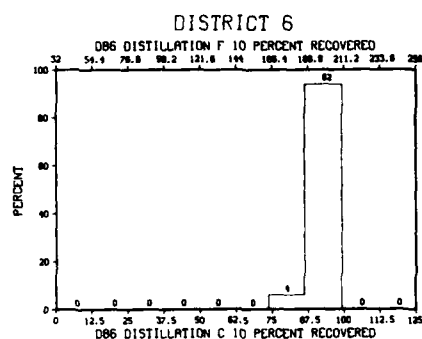
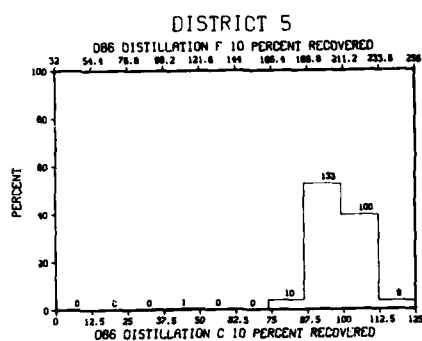


Figure 39. Continued (e-h) D 86 Distillation 10% Recovered Variations:
Districts 5 - 8

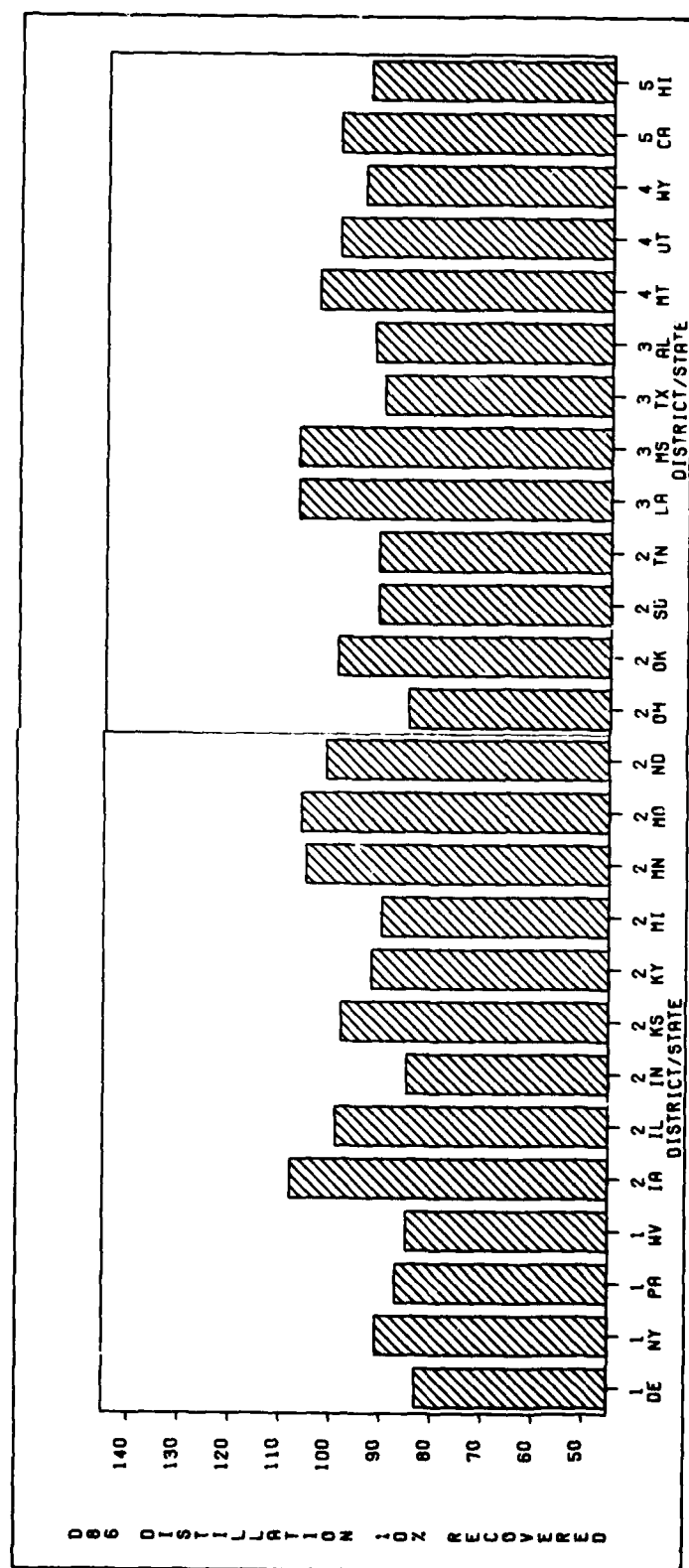


Figure 40. D 86 Distillation 10% Recovered Variations: States

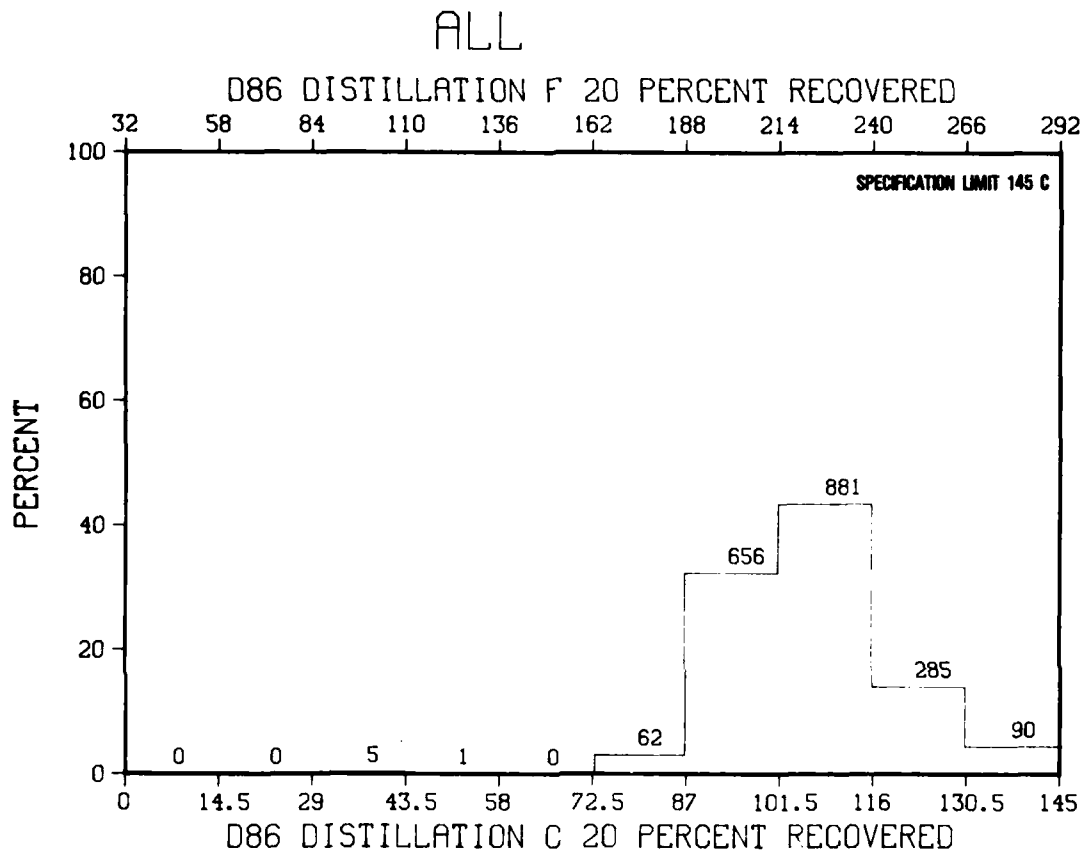


Figure 41. D 86 Distillation 20% Recovered Variations: Worldwide

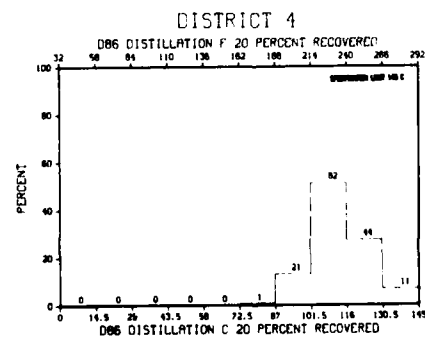
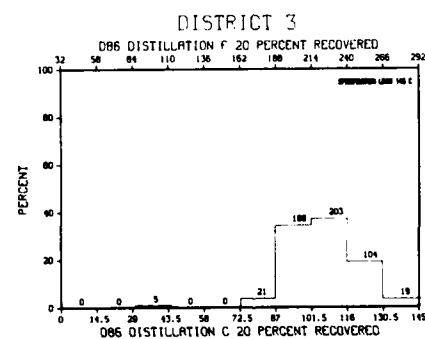
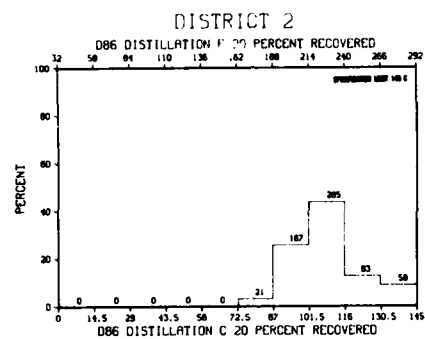
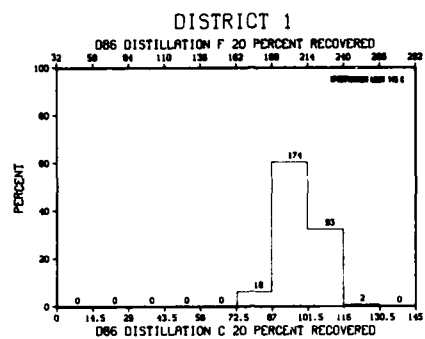


Figure 42. (a-d) D 86 Distillation 20% Recovered Variations:
Districts 1 - 4

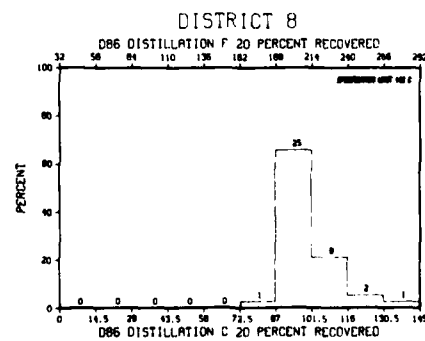
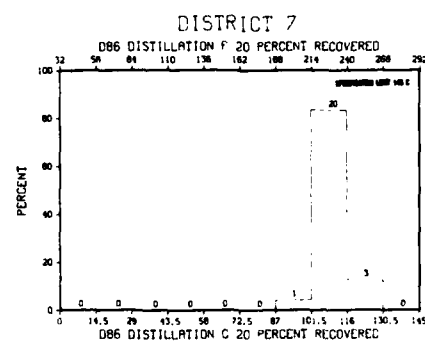
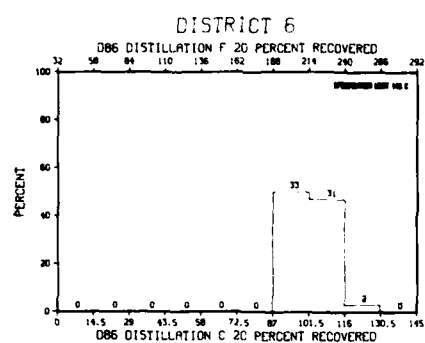
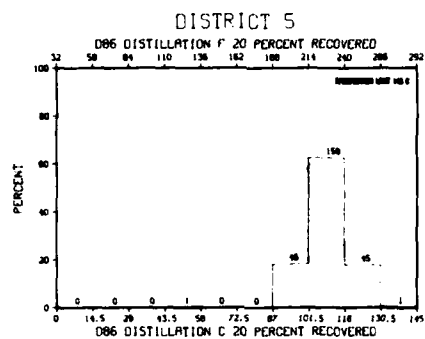


Figure 42. Continued (e-h) D 86 Distillation 20% Recovered
Variations: Districts 5 - 8

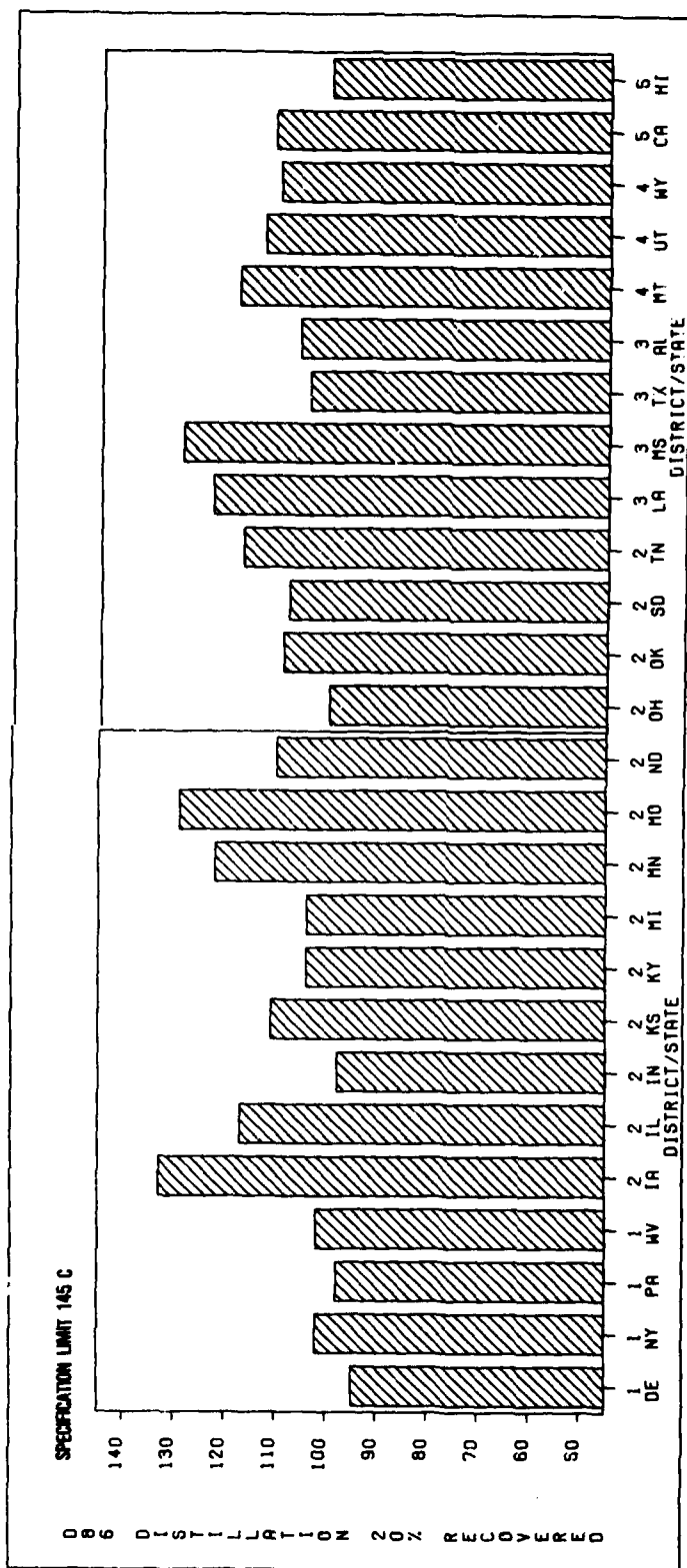


Figure 43. D 86 Distillation 20% Recovered Variations: States

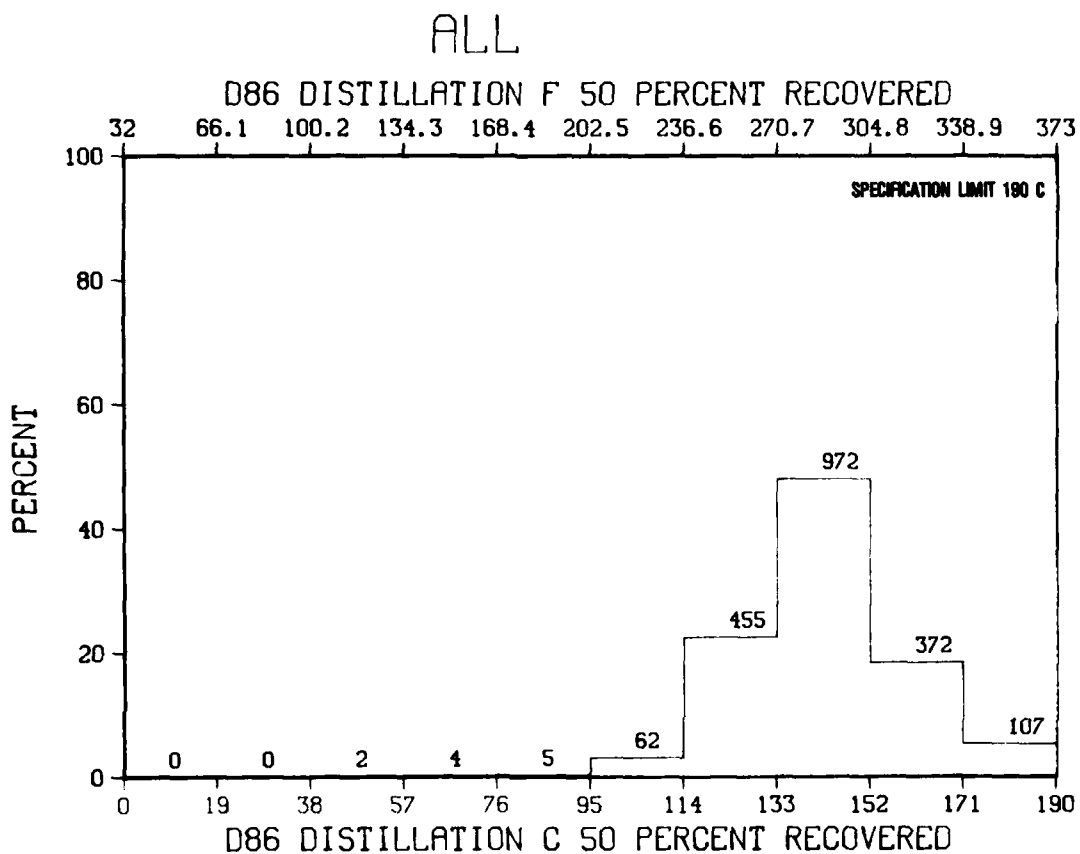


Figure 44. D 86 Distillation 50% Recovered Variations: Worldwide

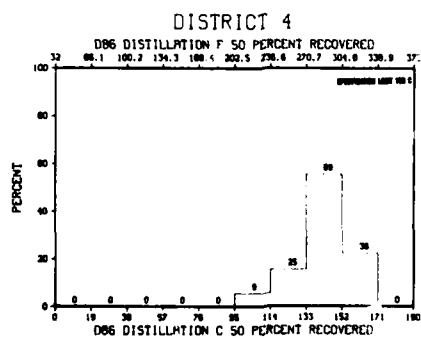
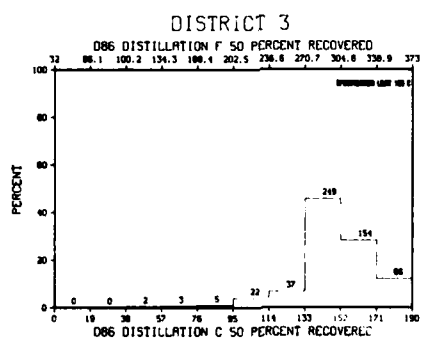
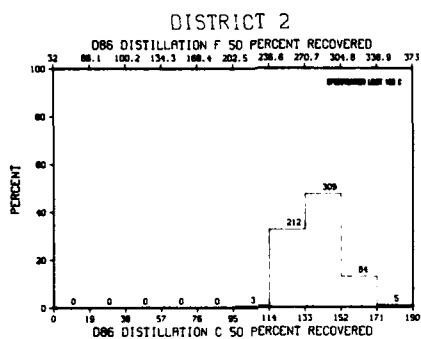
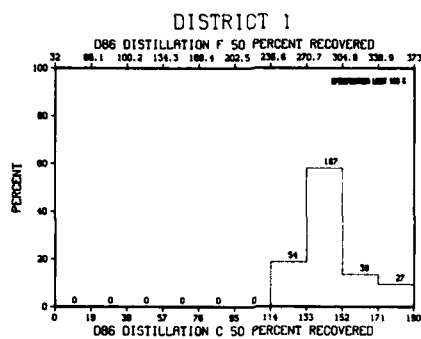


Figure 45. (a-d) D 86 Distillation 50% Recovered Variations: Districts 1 - 4

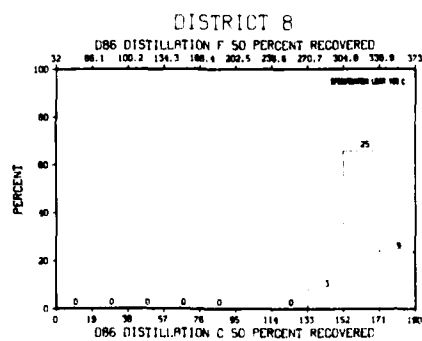
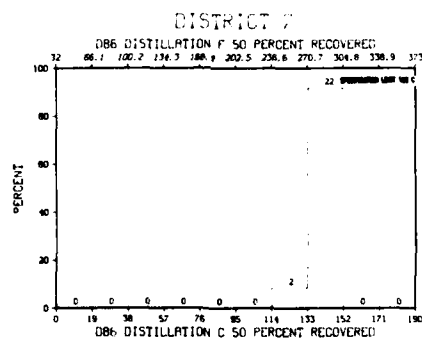
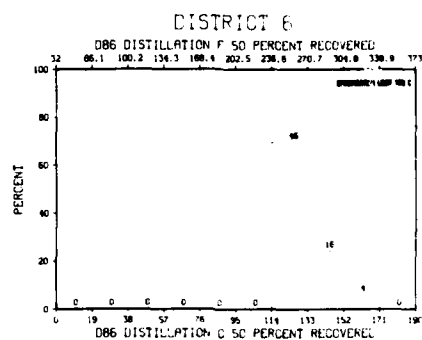
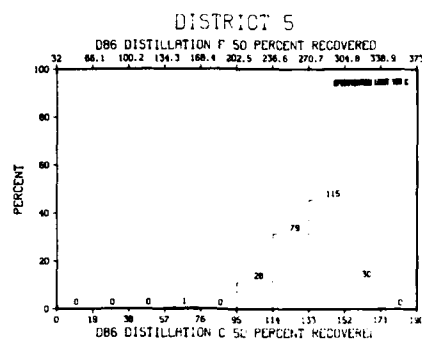


Figure 45. Continued (e-h) D 86 Distillation 50% Recovered
Variations: Districts 5 - 8

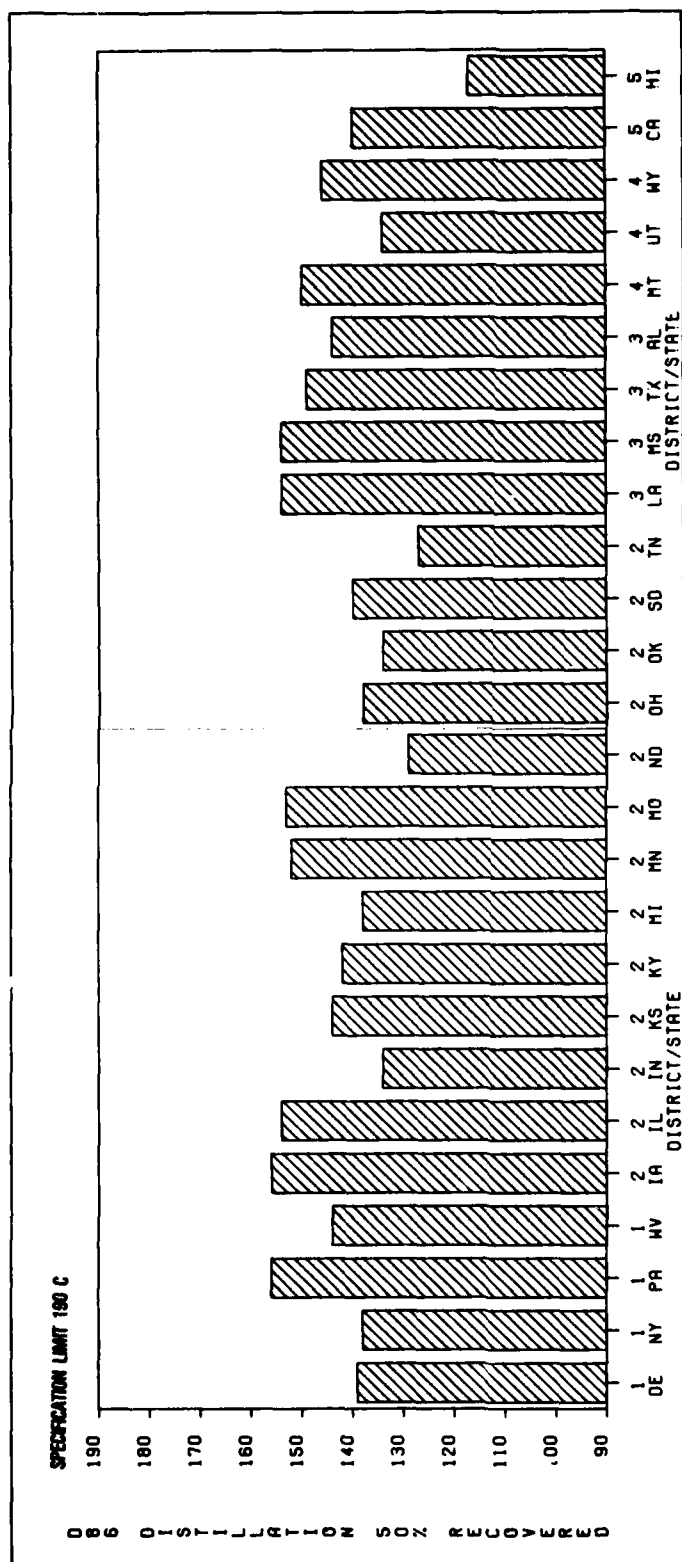


Figure 46. D 86 Distillation 50% Recovered Variations: States

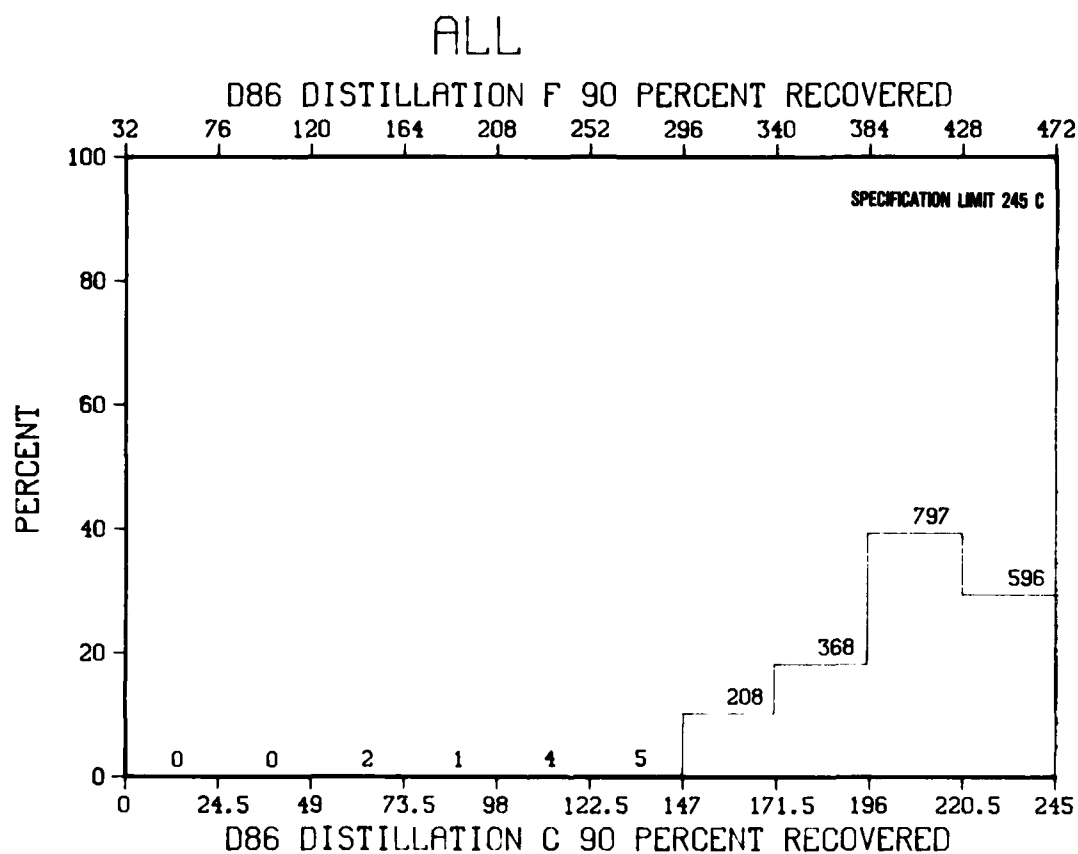


Figure 47. D 86 Distillation 90% Recovered Variations: Worldwide

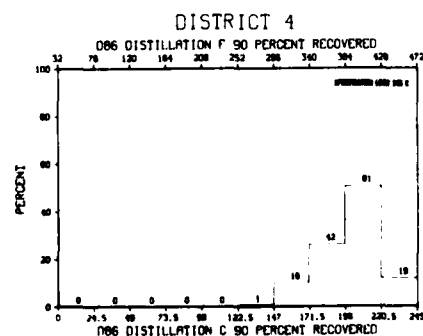
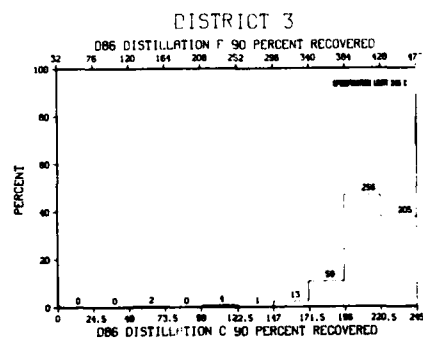
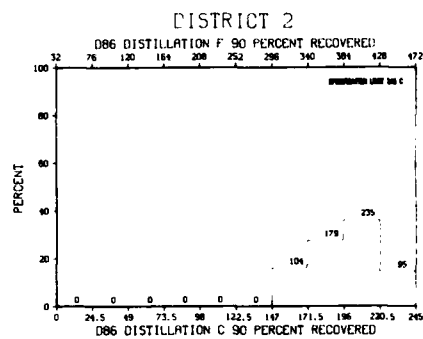
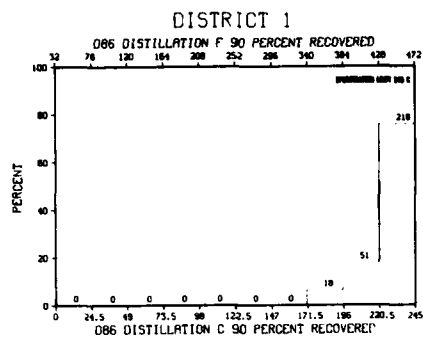


Figure 48. (a-d) D 86 Distillation 90% Recovered Variations:
Districts 5 - 8

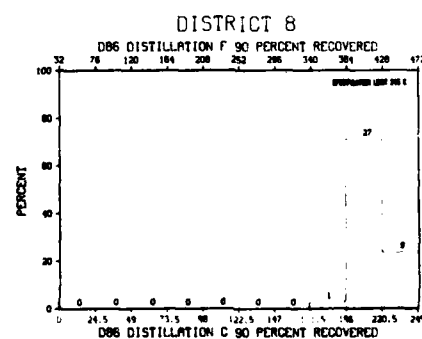
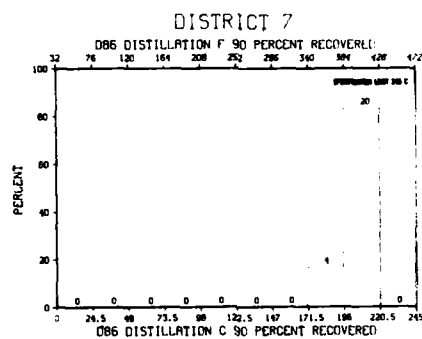
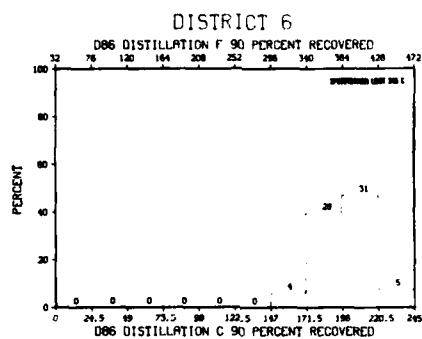
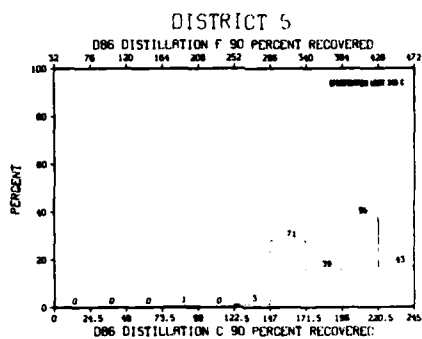


Figure 48. Continued (e-h). D 86 Distillation 90% recovered Variations: Districts 5-8

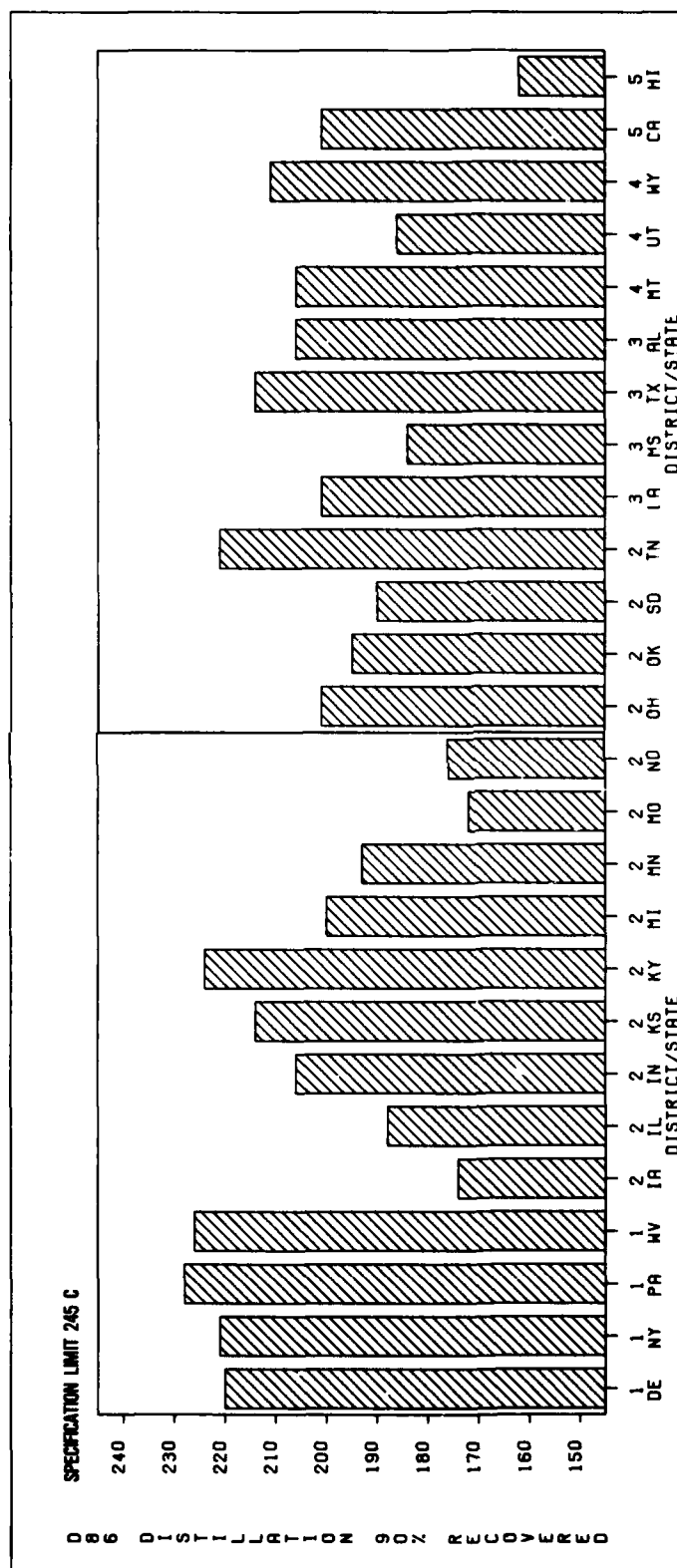


Figure 49. D 86 Distillation 90% Recovered Variations: States

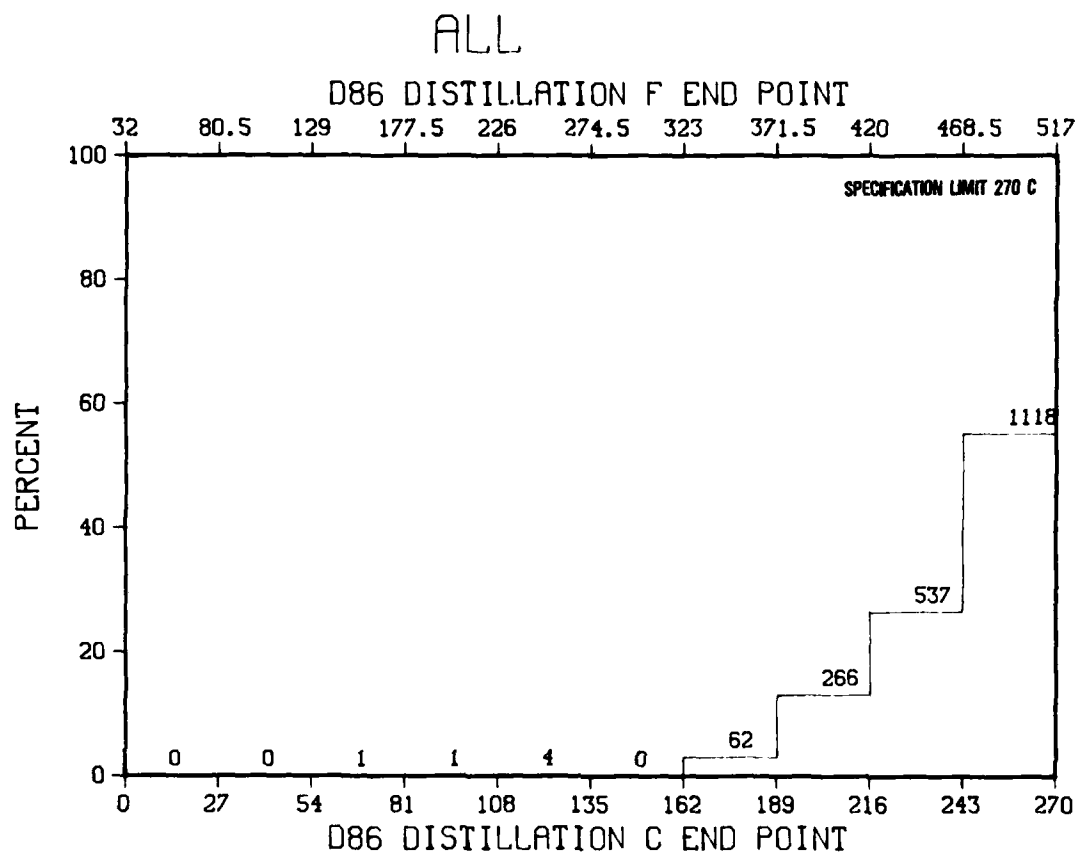


Figure 50. D 86 Distillation End Point Recovered Variations:
Worldwide

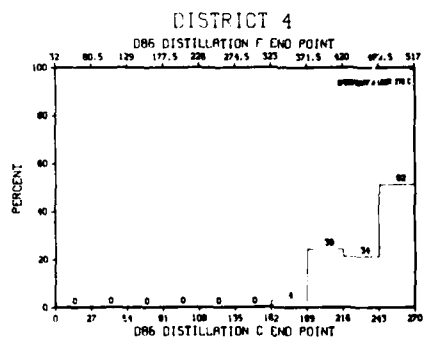
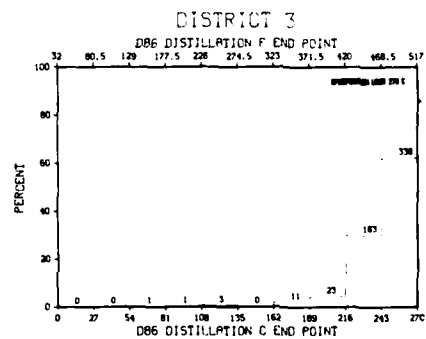
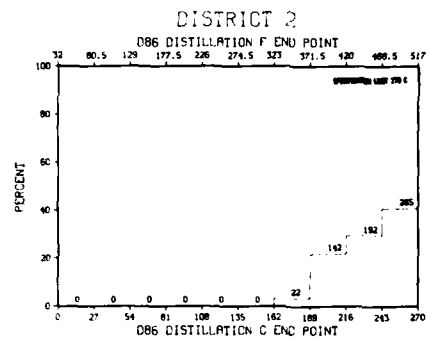
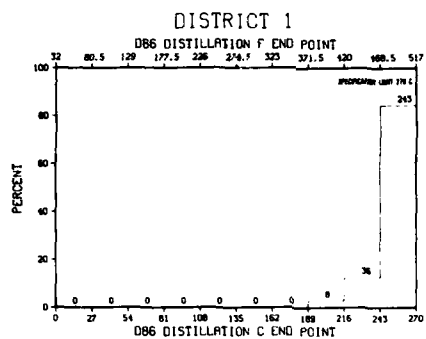


Figure 51. (a-d) D 86 Distillation End Point Variations:
Districts 1 - 4

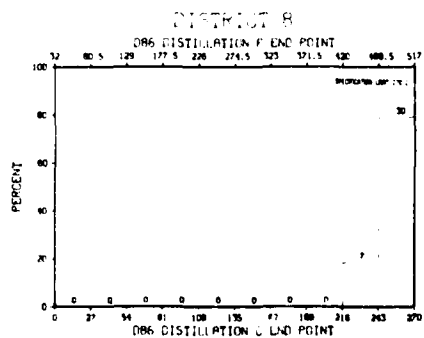
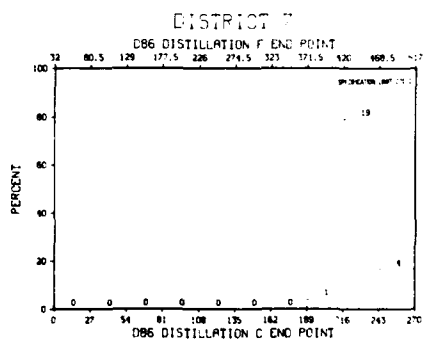
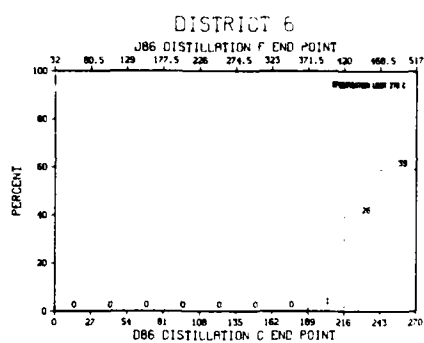
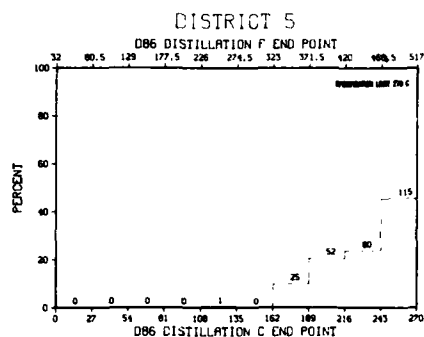


Figure 51. Continued (e-h) D 86 Distillation End Point Variations:
Districts 5 - 8

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THE CHEMICAL AND PHYSICAL PROPERTIES OF JP-4 FOR 1980 -
1981(U) AIR FORCE WRIGHT AERONAUTICAL LABS
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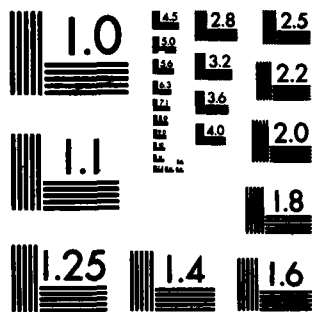
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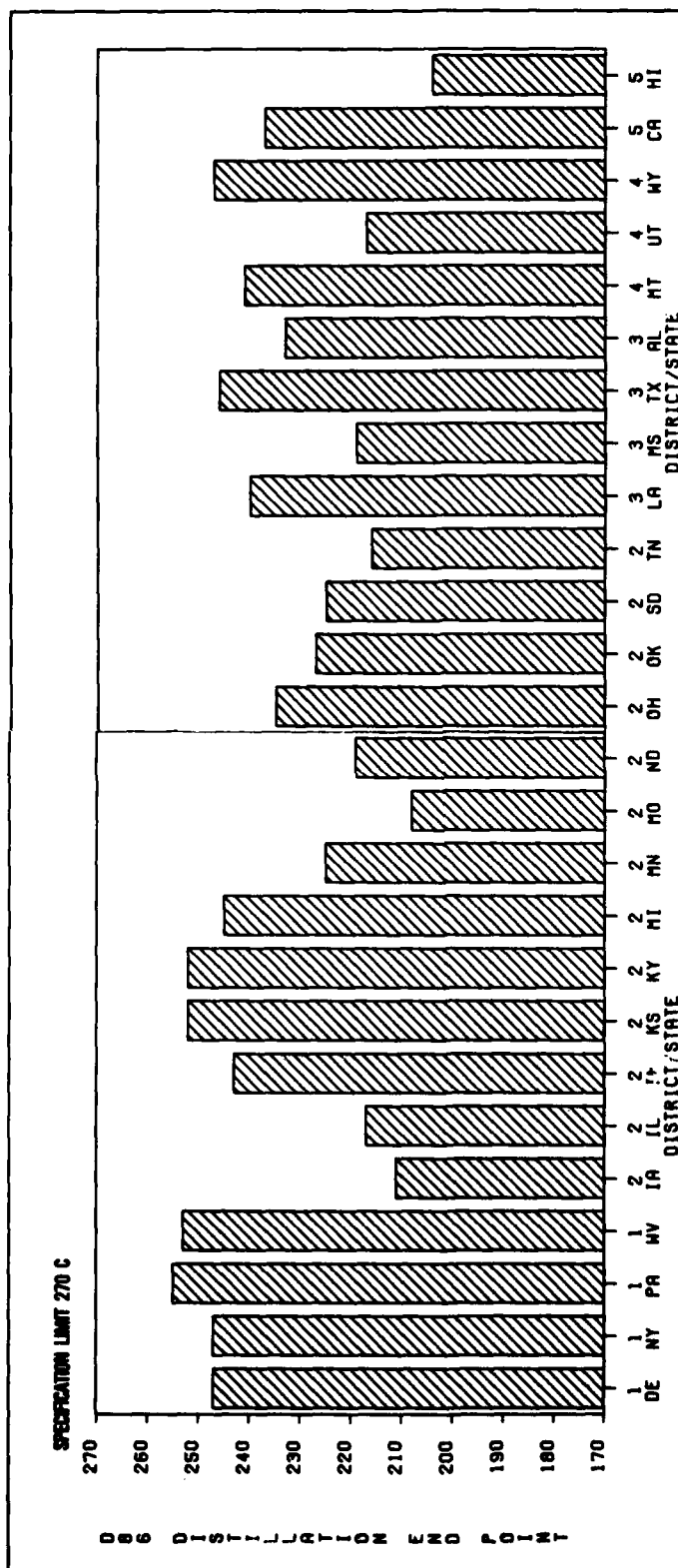


Figure 52. D 86 Distillation End Point Variations: States

7. BOILING RANGE DISTRIBUTION

A small percentage of the refiners in District 3 performed D 2887 simulated distillation. The data for these refiners are presented in the following histograms.

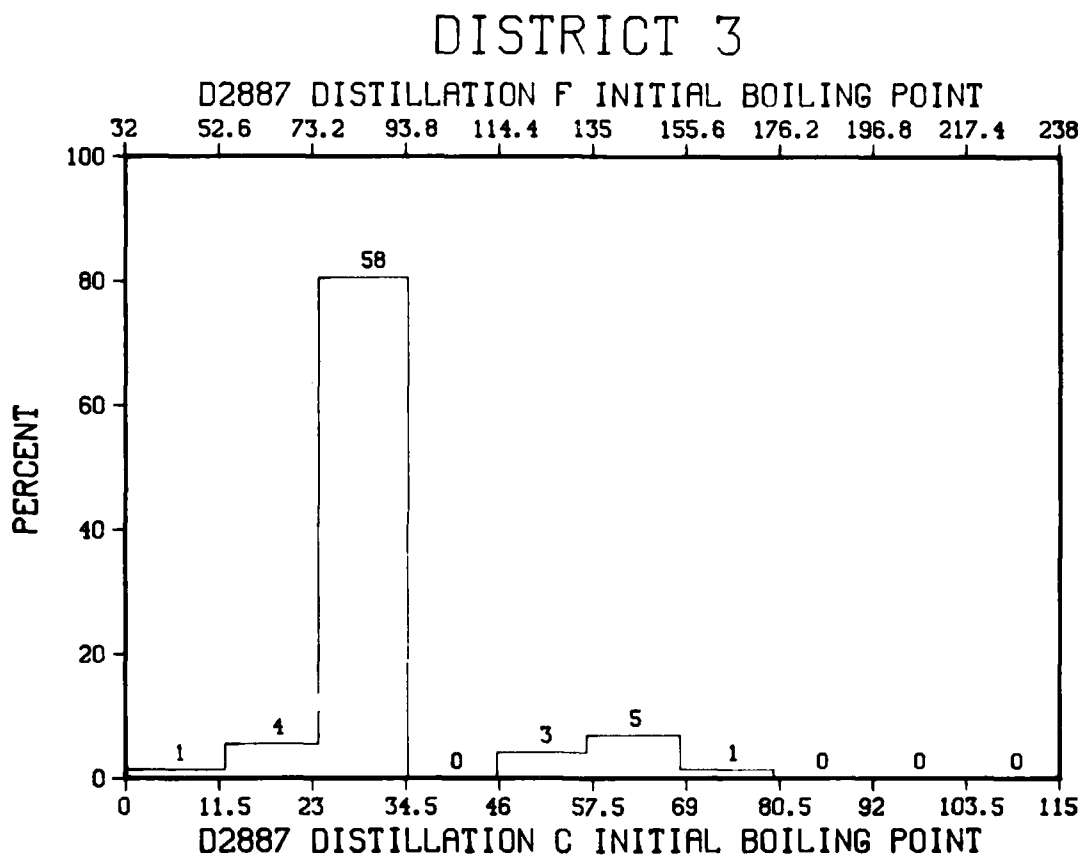


Figure 53. D 2887 Distillation Initial Boiling Point Variations:
District 3

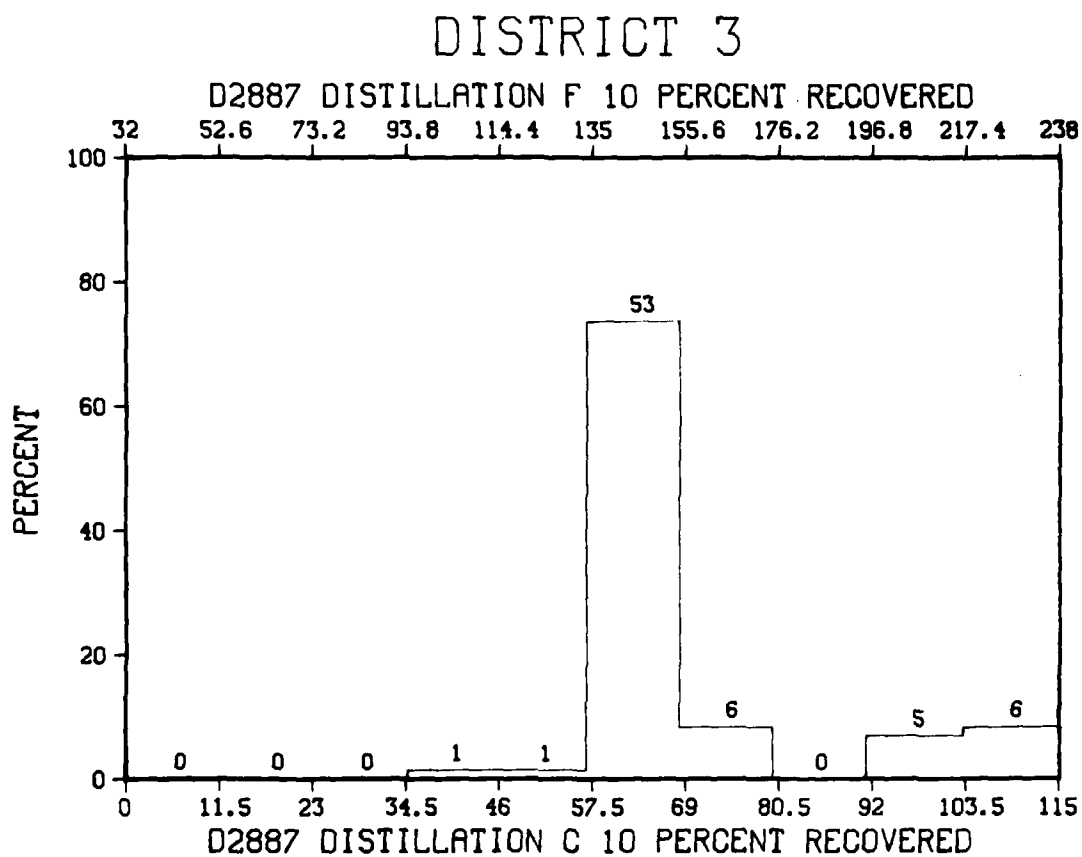


Figure 54. D 2887 Distillation 10% Recovered Variations: District 3

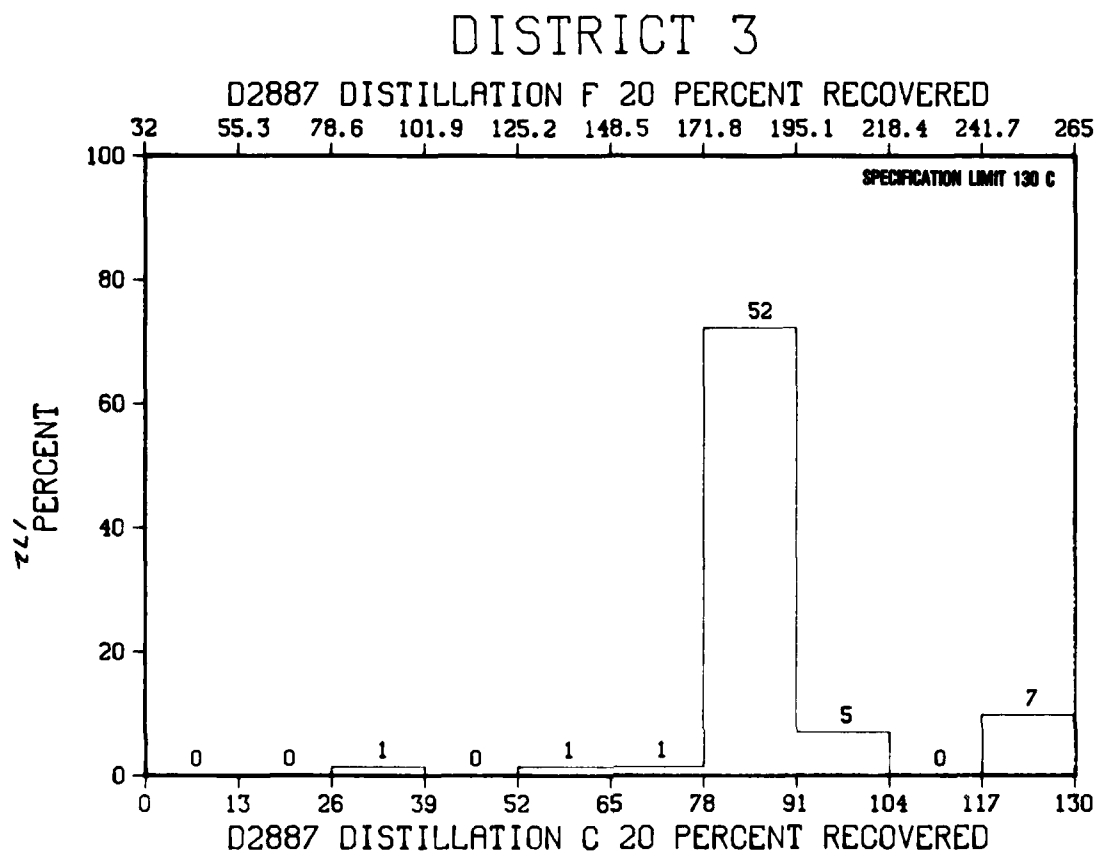


Figure 55. D 2887 Distillation 20% Recovered Variations: District 3

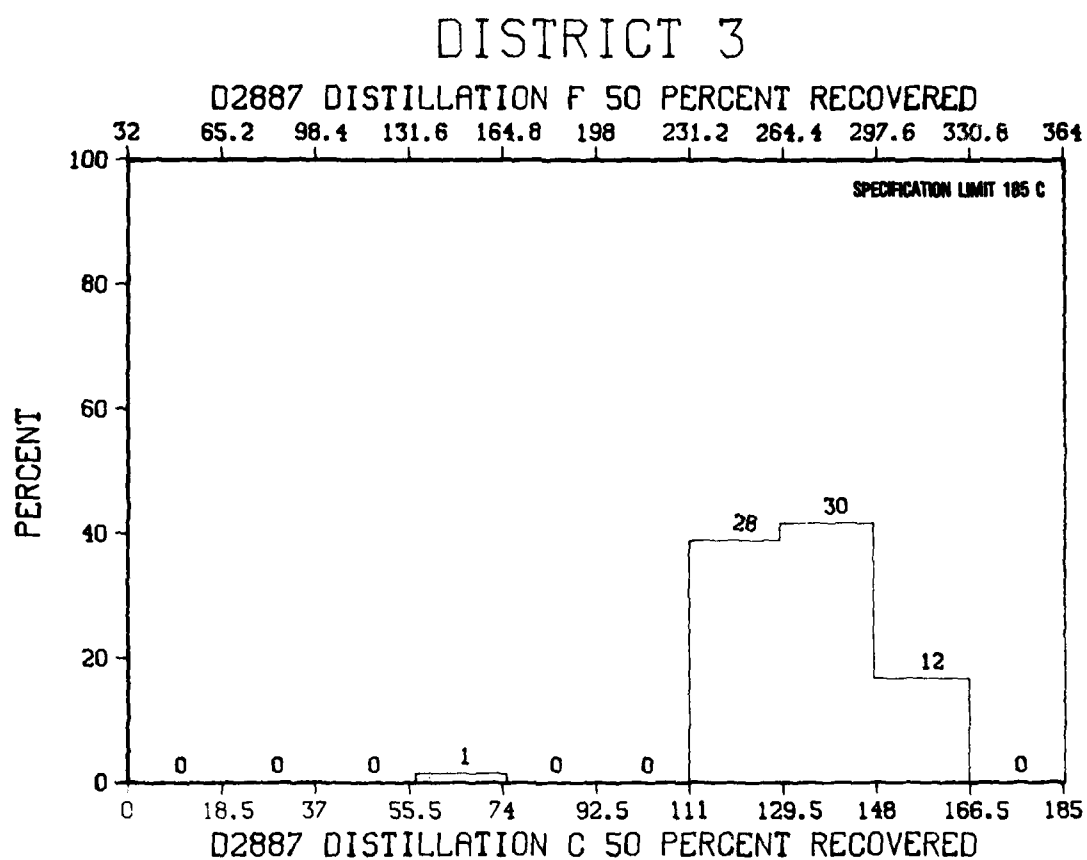


Figure 56. D 2887 Distillation 50% Recovered Variations: District 3

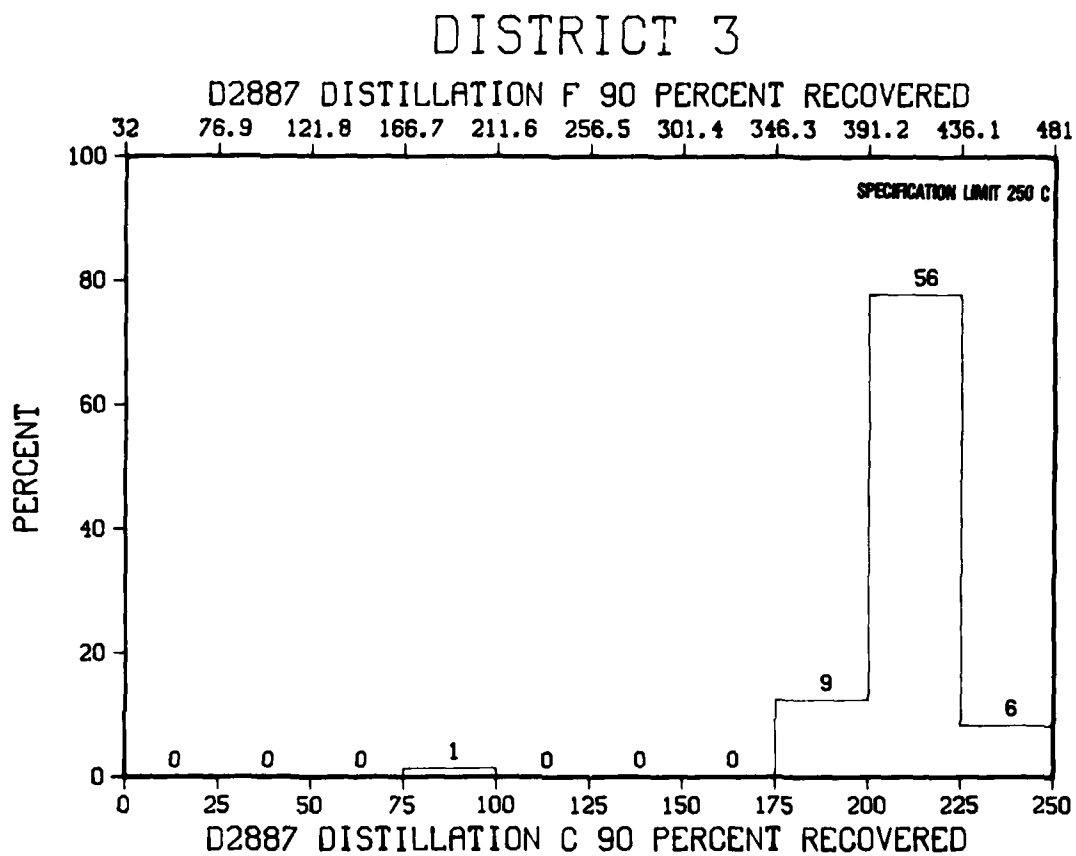


Figure 57. D 2887 Distillation 90% Recovered Variations: District 3

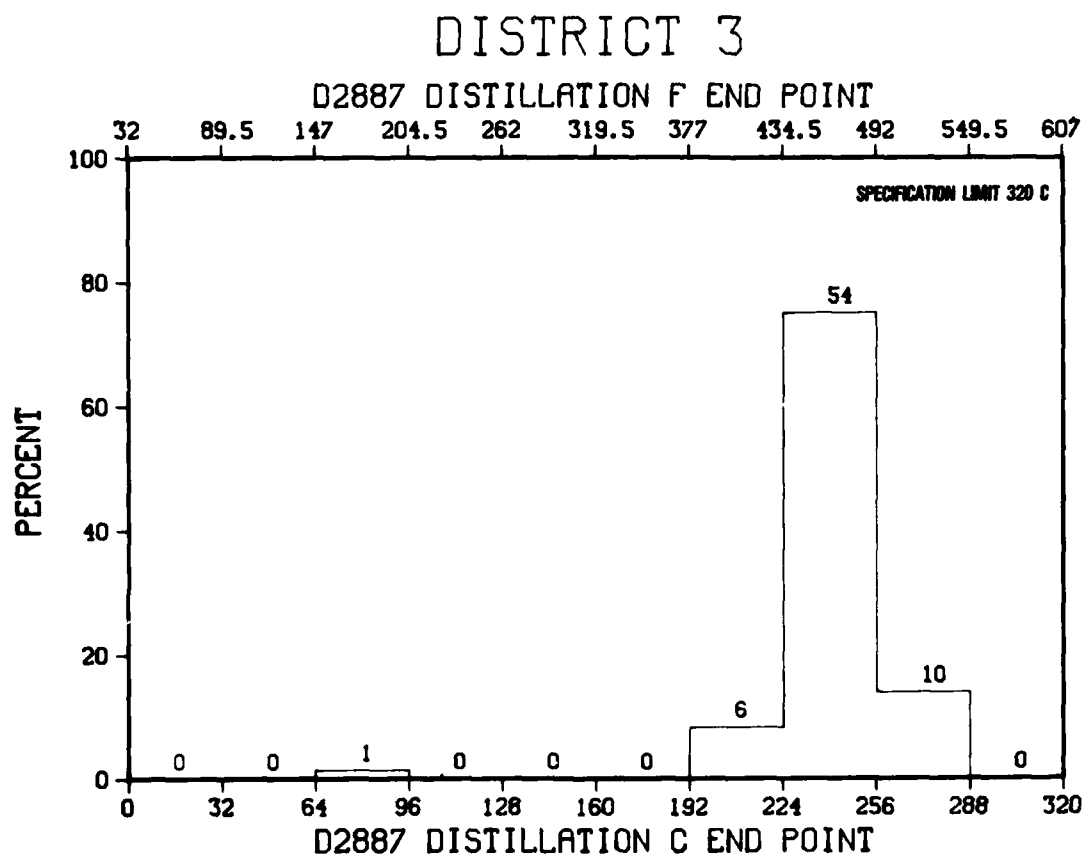


Figure 58. D 2887 Distillation End Point Variations: District 3

8. API GRAVITY

The API gravity of JP-4 samples varies between the specification limits of 45.0 and 57.0. Variations existed among districts worldwide and among the states in the districts that comprise the United States. The "average" API gravity worldwide is 54.2. Within the United States, fuels from Iowa had the lowest "average" API gravity of 51.7; fuels from Pennsylvania had the highest "average" API gravity of 56.5. The "near specification limits" for this test are 45.3 and 56.7. None of the samples fell within the lower "near specification band" and less than 21 percent fell in the upper "near specification band."

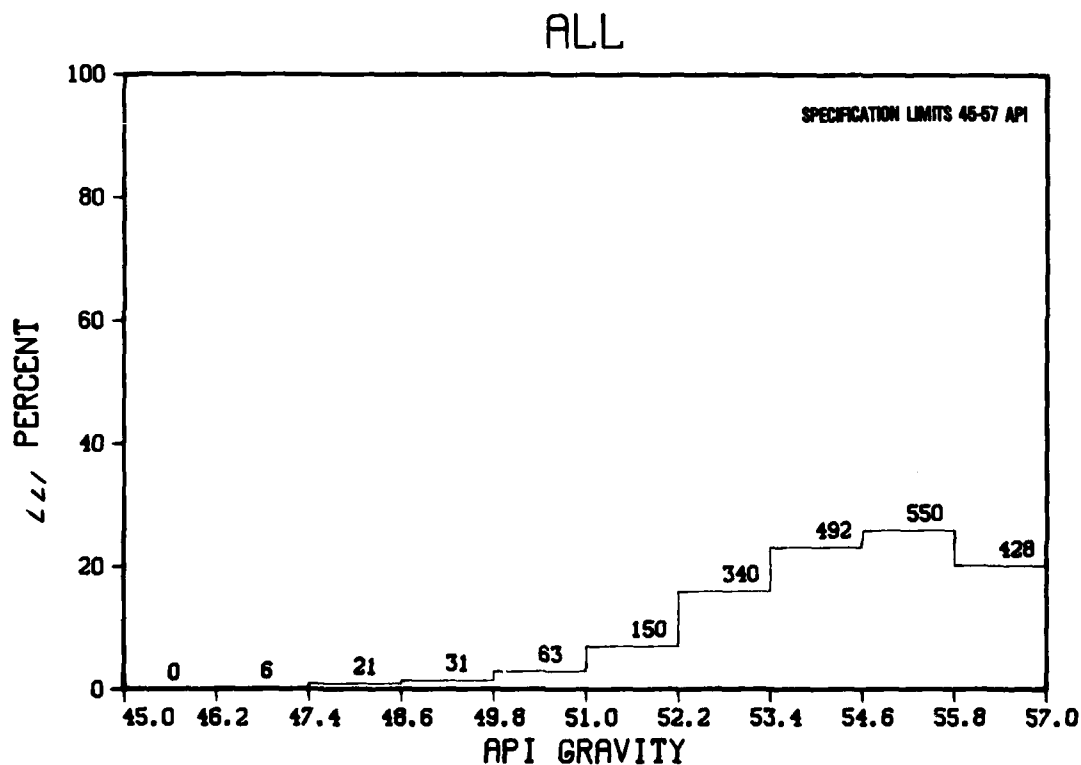


Figure 59. API Gravity Variations: Worldwide

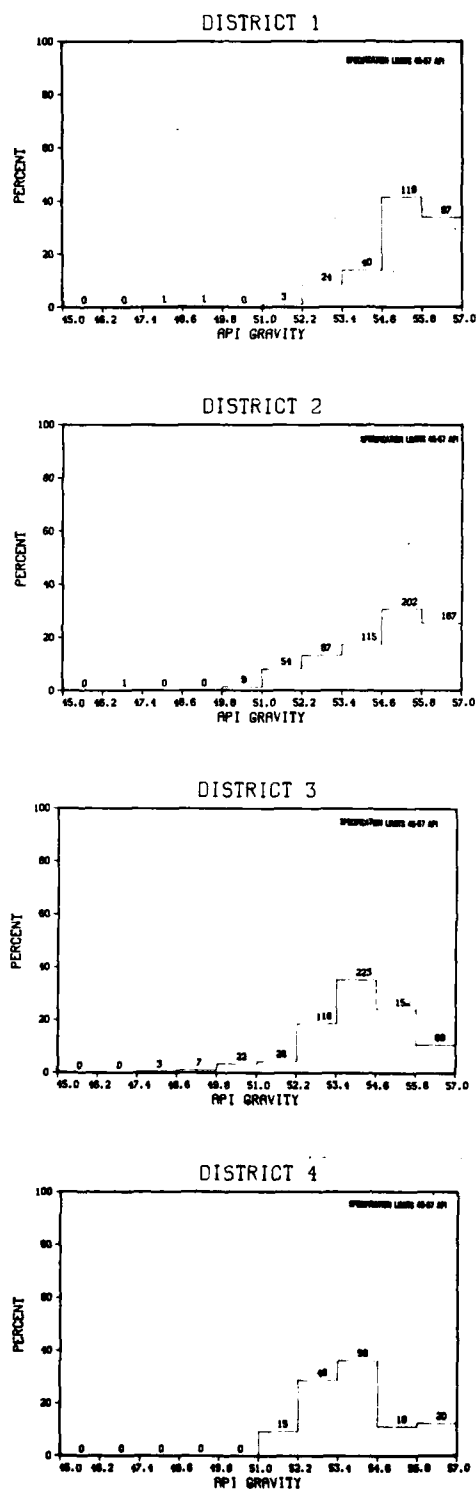


Figure 60. (a-d) API Gravity Variations: Districts 1 - 4

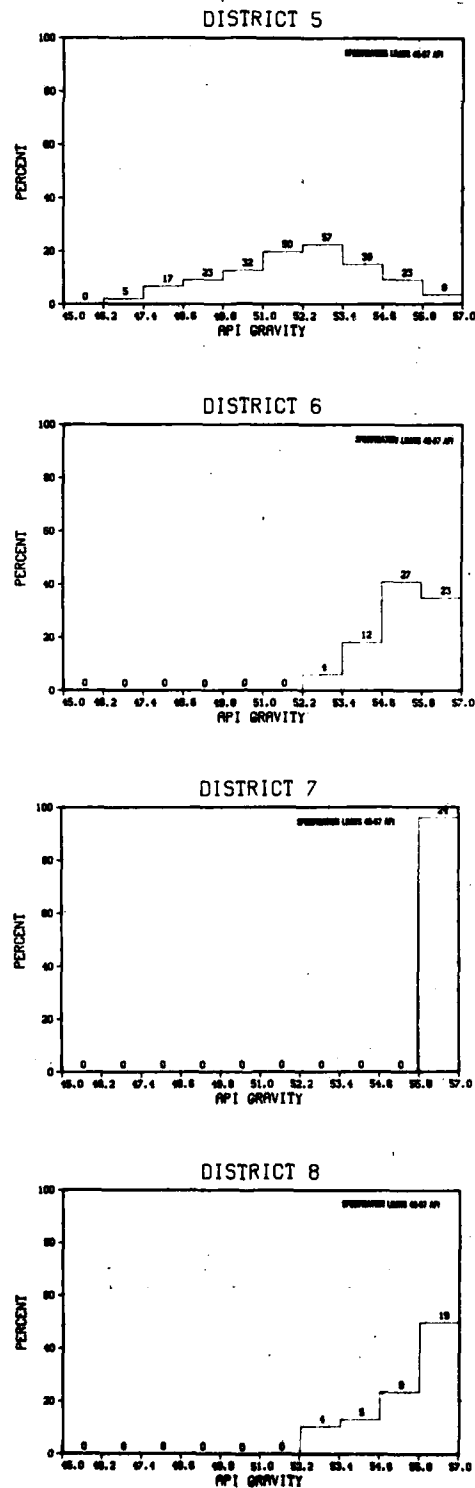


Figure 60. Continued (e-h) API Gravity Variations: Districts 5 - 8

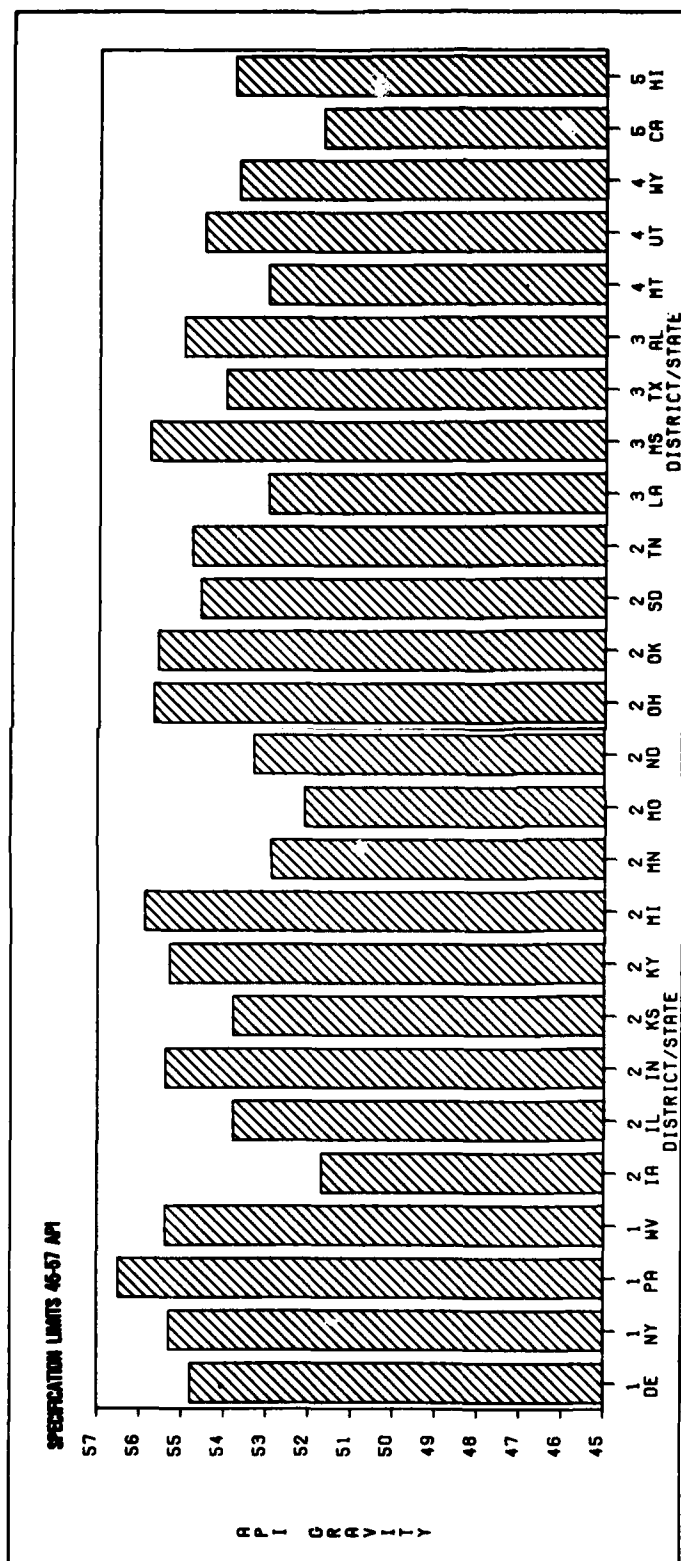


Figure 61. API Gravity Variations: States

9. REID VAPOR PRESSURE

The Reid vapor pressure of JP-4 samples varied between the specification limits of 2.0 and 3.0 psi. The variation was evident among districts and between the states that comprise the districts of the United States. The "average" Reid vapor pressure worldwide was 2.6 psi. Within the United States, fuels from Montana had the lowest "average" Reid vapor pressure of 2.3 psi; fuels from Indiana and Ohio had the highest "average" Reid vapor pressure of 2.8 psi. The "near specification limits" for this test are 2.35 and 2.65. Less than 26 percent of the lots of JP-4 fell within the lower "near specification band" and less than 46 percent of the lots of JP-4 fell within the upper "near specification band."

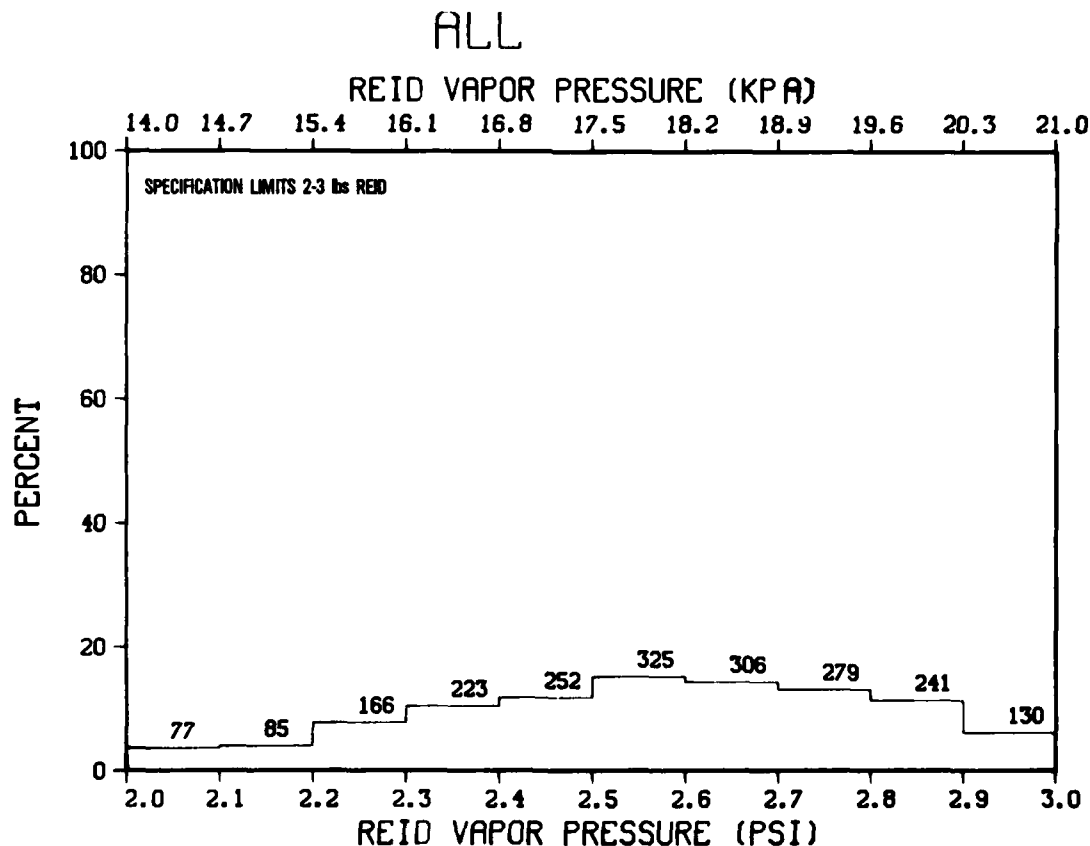


Figure 62. Reid Vapor Pressure Variations: Worldwide

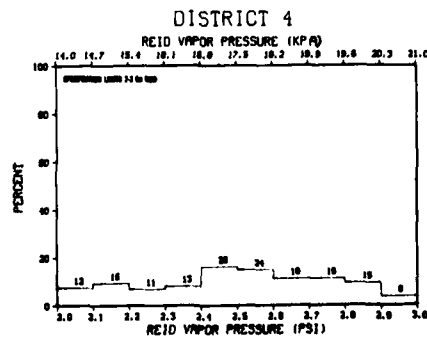
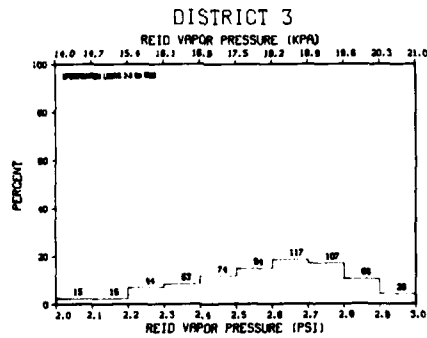
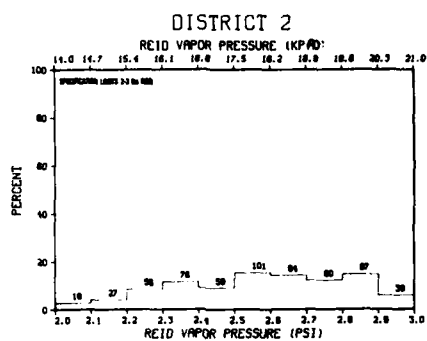
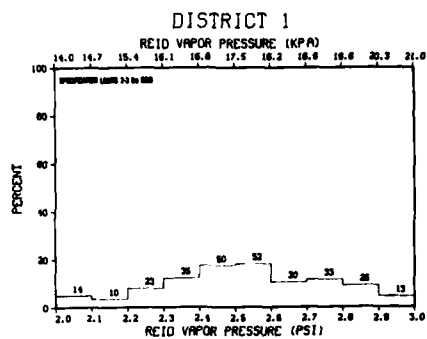


Figure 63. (a-d) Reid Vapor Pressure Variations: Districts 1 - 4

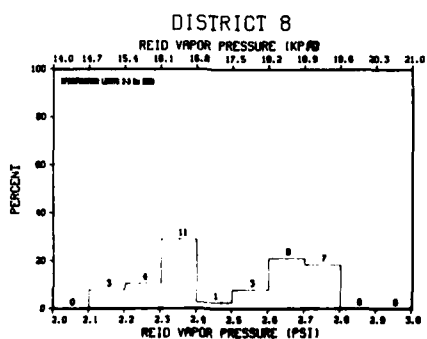
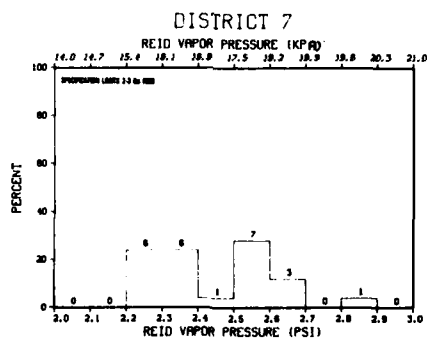
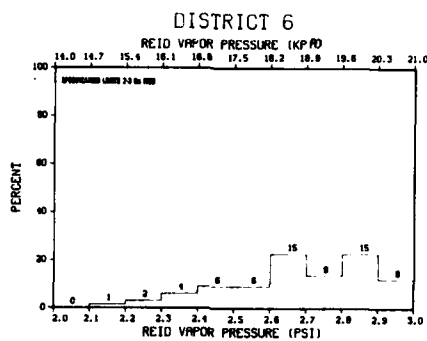
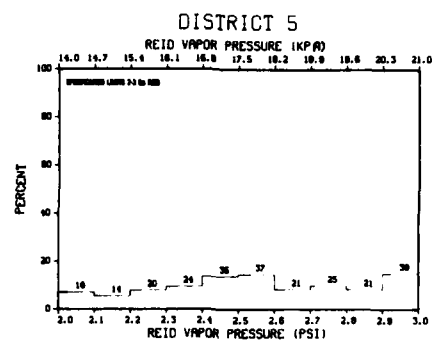


Figure 63. Continued (e-h) Reid Vapor Pressure Variations:
Districts 5 - 8

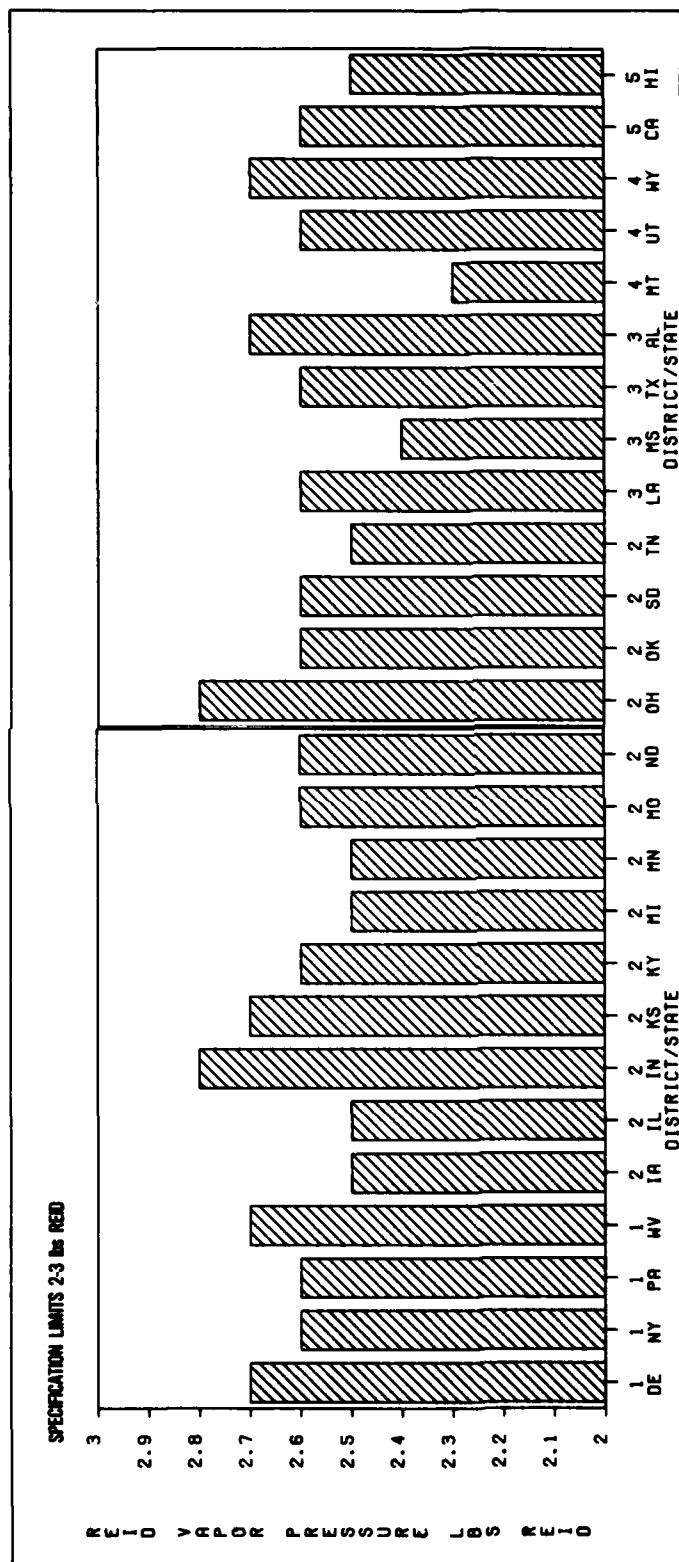


Figure 64. Reid Vapor Pressure Variations: States

10. HEAT OF COMBUSTION

The net heat of combustion for the JP-4 samples was calculated from the API gravity, average distillation temperature at 10, 50, and 90 percent recovered by D 86 distillation, aromatic content, and sulfur content of the fuel samples. Details of this calculation are presented in Section II of this report. Variation existed between the specification limit of 18400 and 19,000 Btu/lb. Variation in the heat of combustion varied among districts as well as between states within the United States. The "average" heat of combustion worldwide was 18702 Btu/lb. Within the United States, fuels from Hawaii had the lowest "average" heat of combustion of 18574 Btu/lb; fuels from Pennsylvania had the highest "average" heat of combustion of 18794 Btu/lb. The "near specification limit" for this test is 18420 Btu/lb. Less than 0.5 percent of the samples fell within this "near specification band."

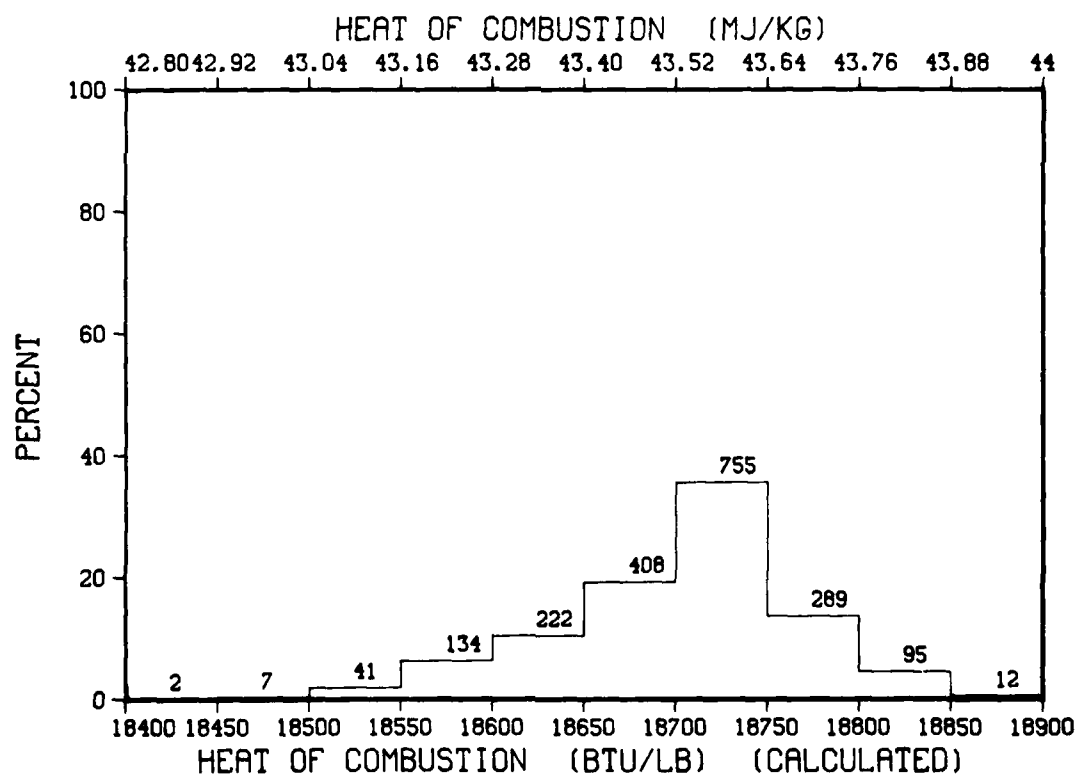


Figure 65. Heat of Combustion Variations: Worldwide

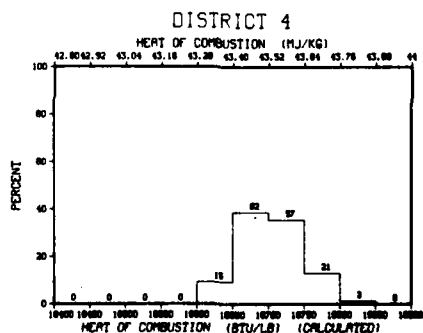
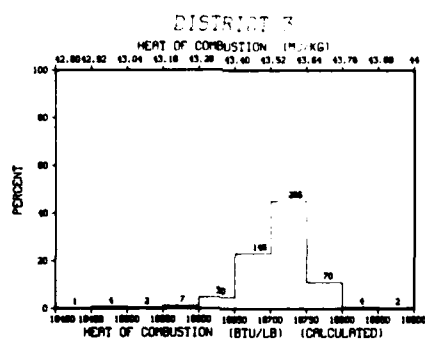
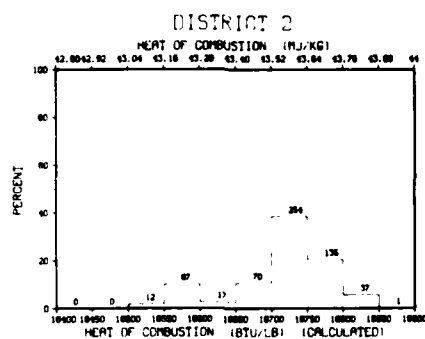
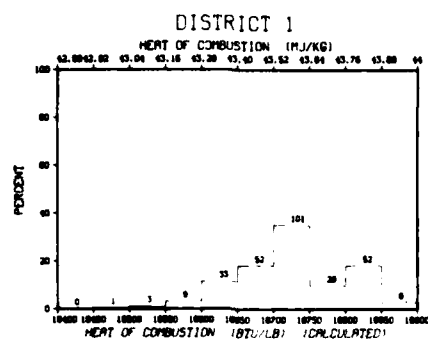


Figure 66. (a-d) Heat of Combustion Variations: Districts 1 - 4

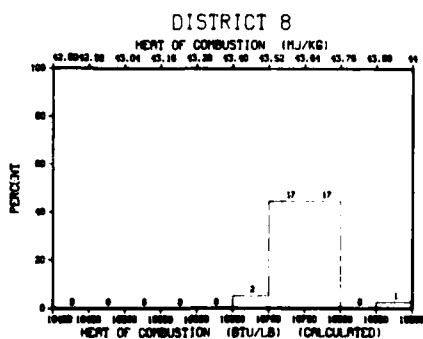
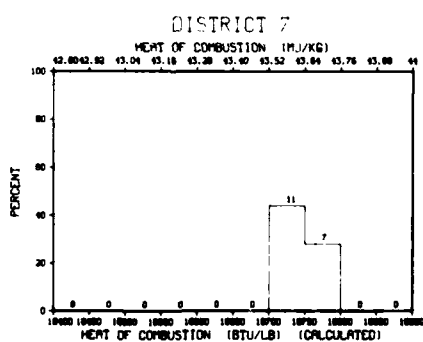
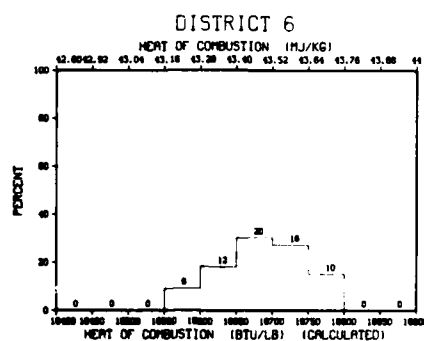
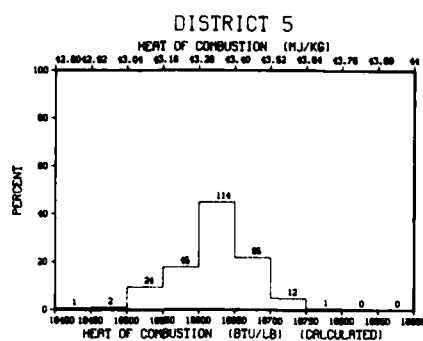


Figure 66. Continued (e-h) Heat of Combustion Variations:
Districts 5-8

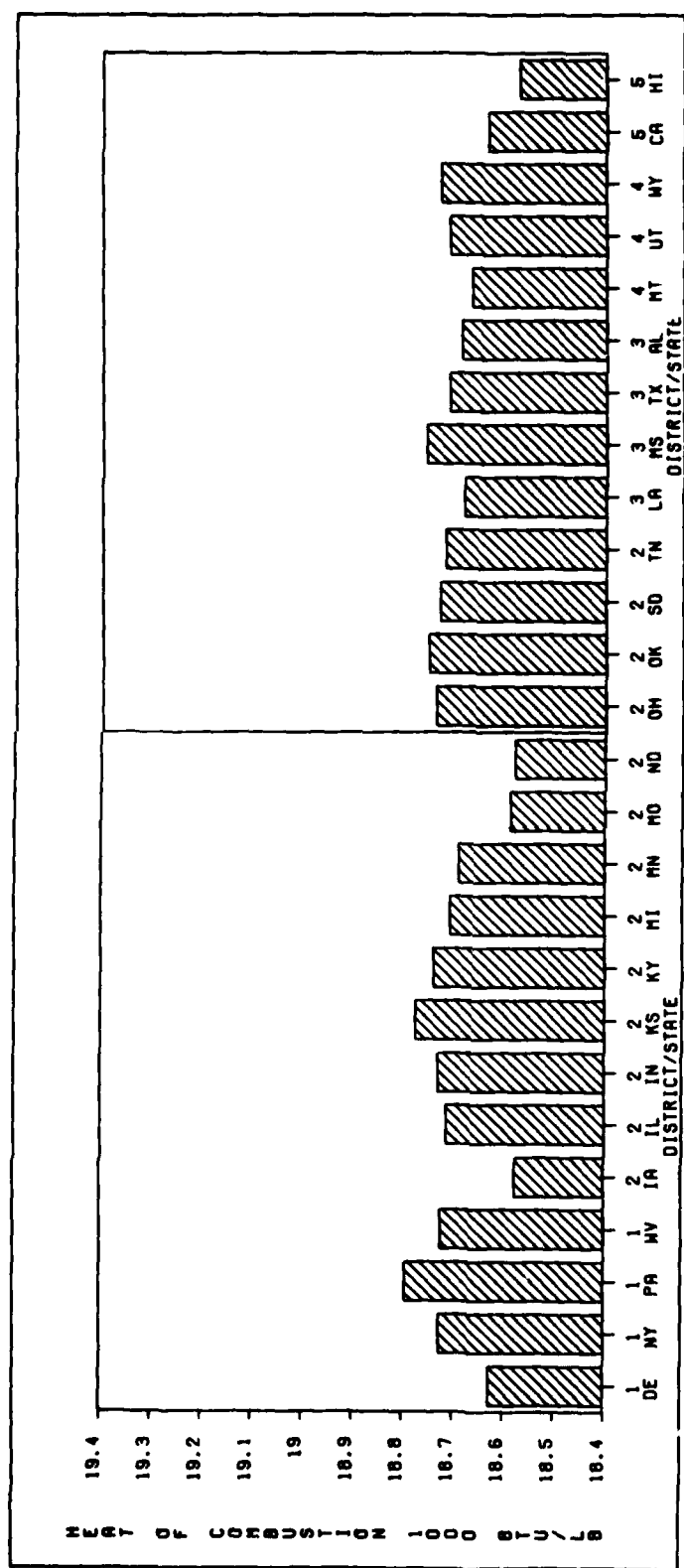


Figure 67. Heat of Combustion Variations: States

11. HYDROGEN CONTENT

The hydrogen content of the JP-4 fuel samples was calculated from the API Gravity, the average distillation temperatures at 10, 50 and 90 percent recovered, and the aromatic content of the fuel. Details of this calculation are presented in Section II of this report. Variations exist worldwide between the specification limit of 13.6 weight percent and 15.0 weight percent. Variations existed among districts and among the states which comprise the United States. The "average" hydrogen content worldwide was 14.3 weight percent hydrogen. Within the United States, fuels from Iowa, North Dakota, and Hawaii had the lowest "average" hydrogen content of 13.8 weight percent; fuels from Pennsylvania, Mississippi, and Kansas had the highest "average" hydrogen content of 14.6 weight percent. The "near specification limit" for this test is 13.7 weight percent. Approximately three percent of the samples fell within this "near specification band."

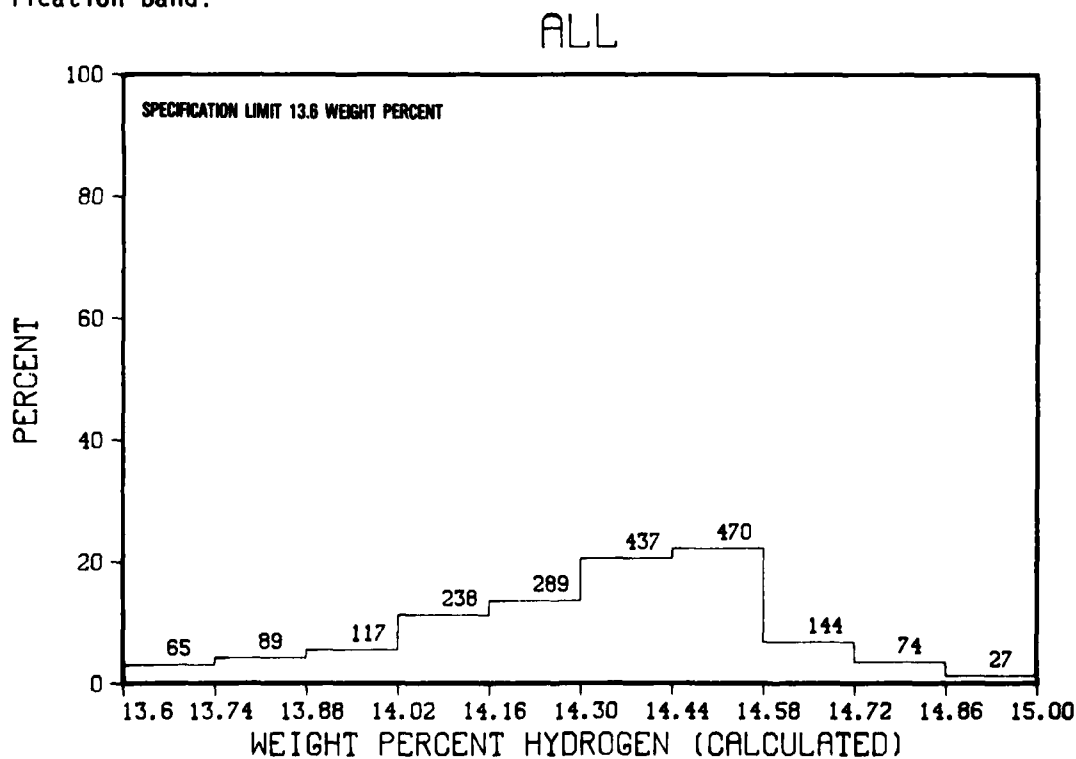


Figure 68. Hydrogen Content Variations: Worldwide

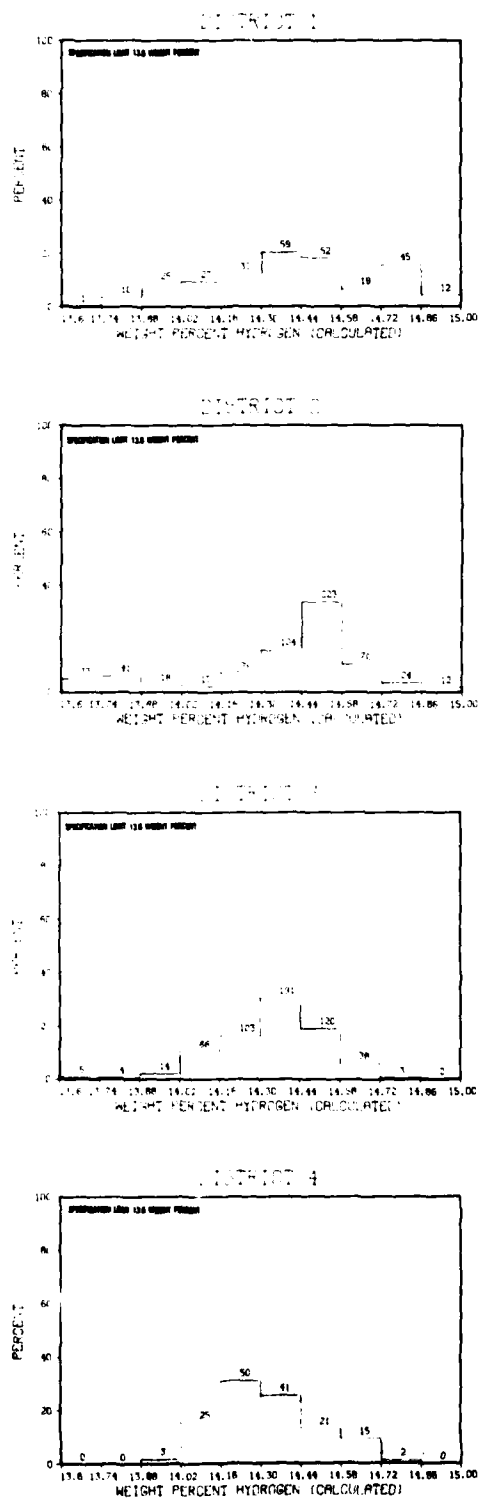


Figure 69. (a-d) Hydrogen Content Variations: Districts 1 - 4

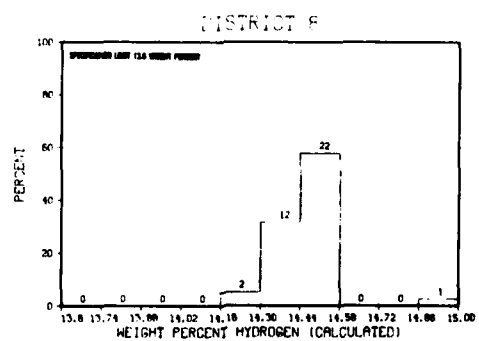
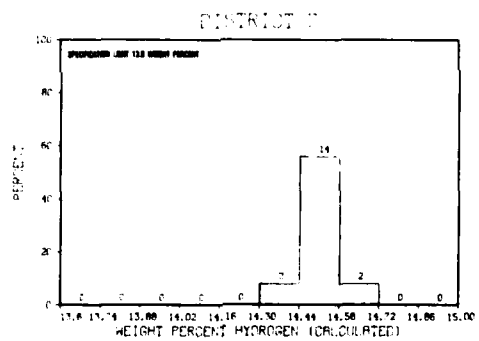
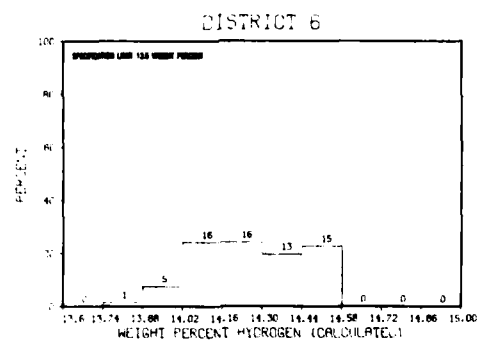
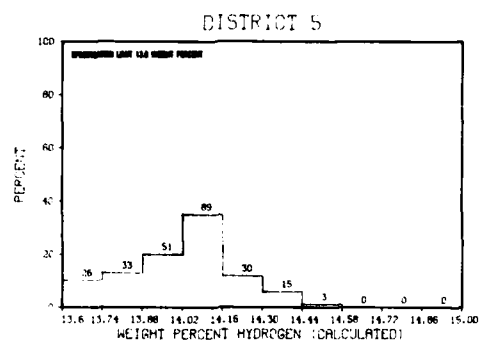


Figure 69. Continued (e-h) Hydrogen Content Variations: Districts 5 - 8

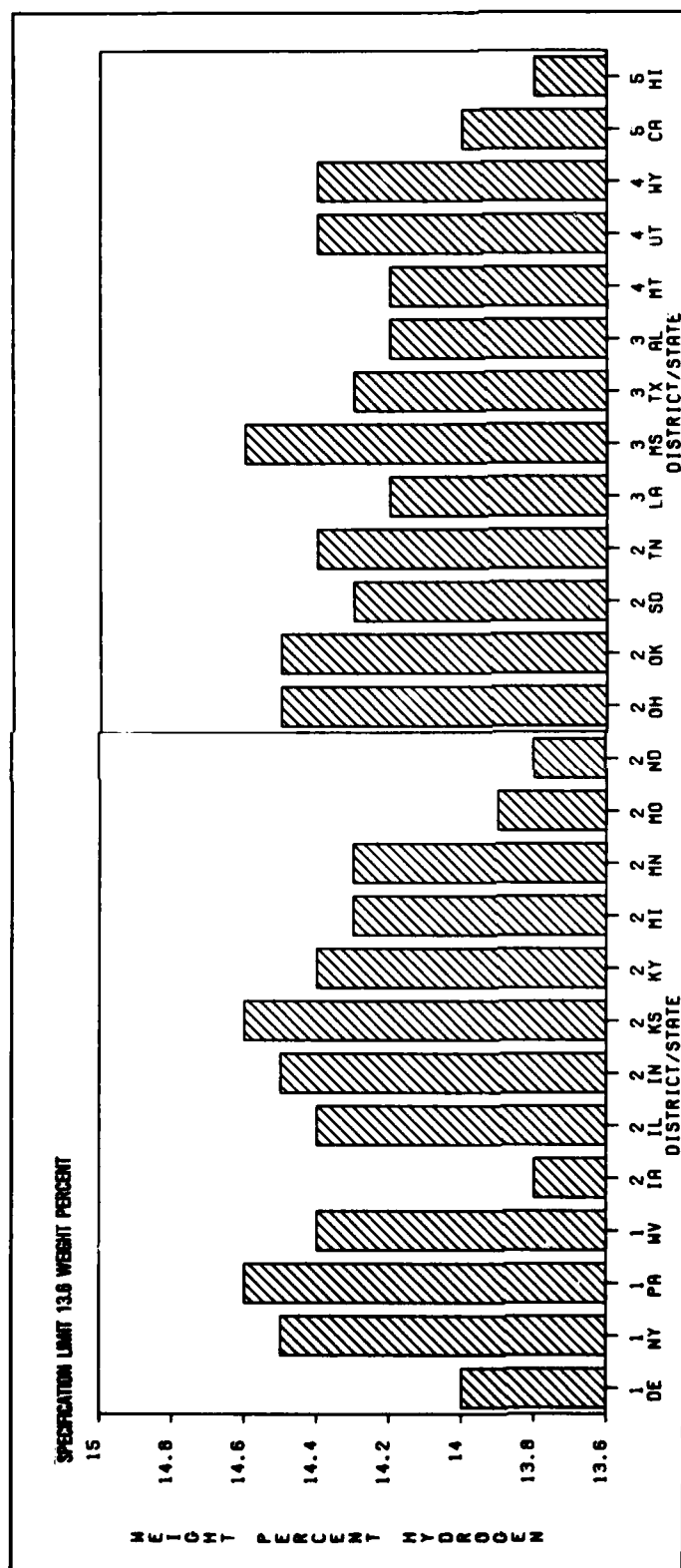


Figure 70. Hydrogen Content Variations: States

12. SMOKE POINT

The "average" smoke point for JP-4 varies worldwide between the specification limit of 20.0 millimeters and 40.0 millimeters. Variations exist among districts and within the states that comprise Districts 1 through 8. The "average" smoke point worldwide was 26.9mm. Within the United States, fuels from Illinois had the lowest "average" smoke point of 21.5mm; fuels from Mississippi had the highest average smoke point of 32.2mm. The "near specification limit" for this test was 23.0 millimeters. Less than 32 percent of the samples fell within this "near specification band."

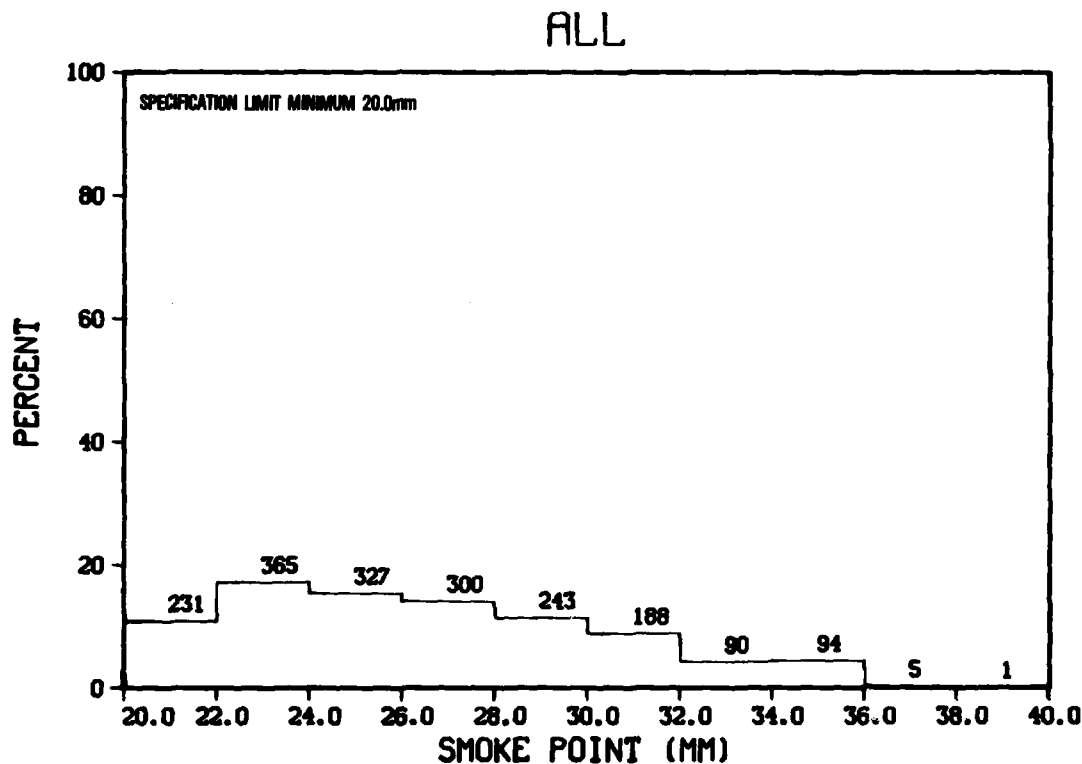


Figure 71. Smoke Point Variations: Worldwide

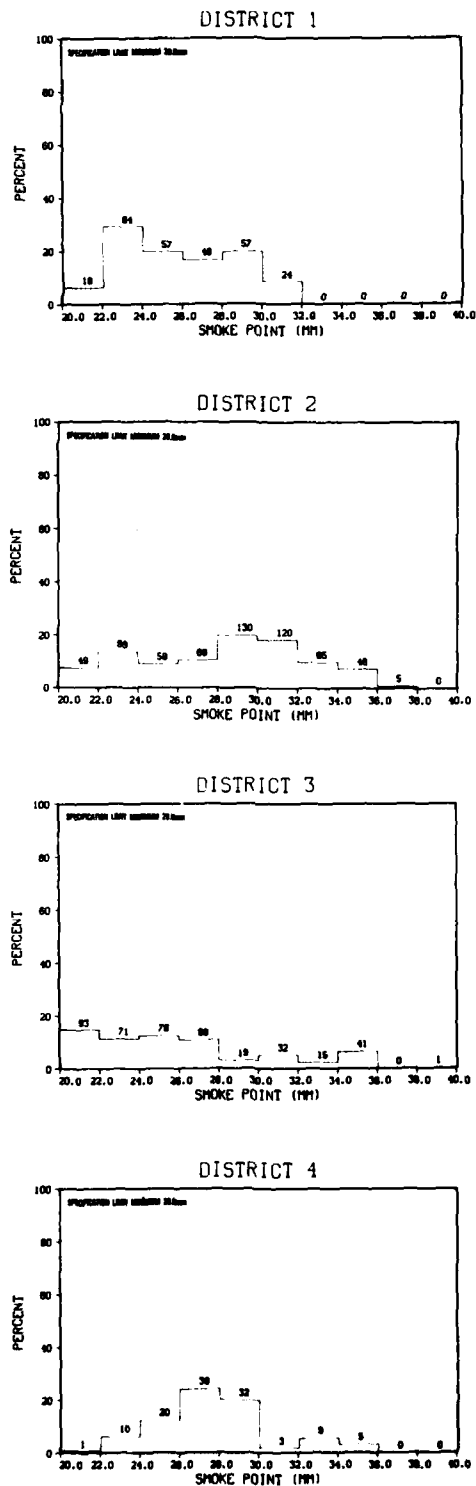


Figure 72. (a-d) Smoke Point Variations: Districts 1 - 4

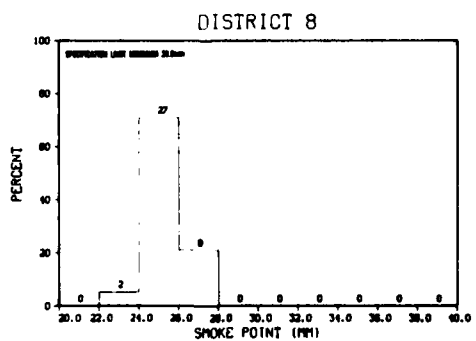
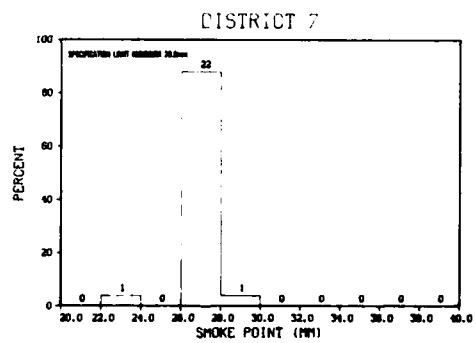
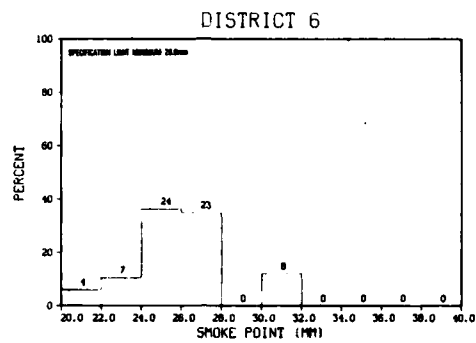
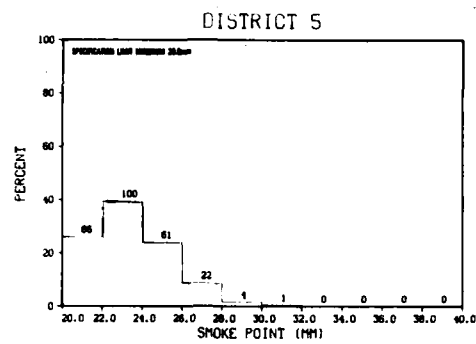


Figure 72. Continued (e-h) Smoke Point Variations: Districts 5 - 8

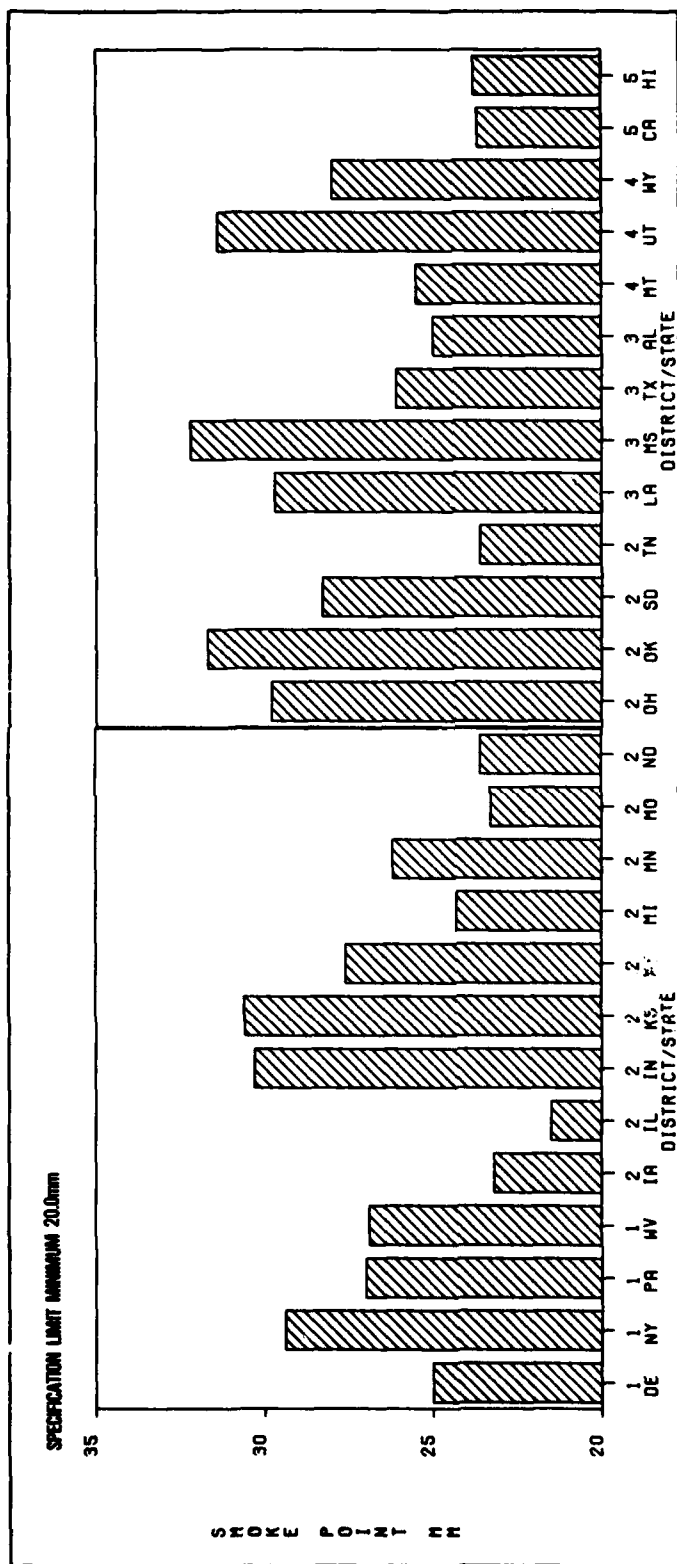


Figure 73. Smoke Point Variations: States

13. THERMAL STABILITY

The thermal stability of JP-4 was measured in two ways, 1) by the pressure drop across a filter, and 2) the tube visual color deposit code. Variations existed worldwide between 0.0 and the specification limit of 25.0mm of Hg pressure drop across the filter. Most of the samples worldwide had a pressure drop of 1mm of Hg or less. The tube deposit code worldwide was less than three, with all but 33 of the samples reporting a deposit code of one or less, signifying minimal deposit formed. All samples with a deposit code of greater than one comprised less than two percent of the samples.

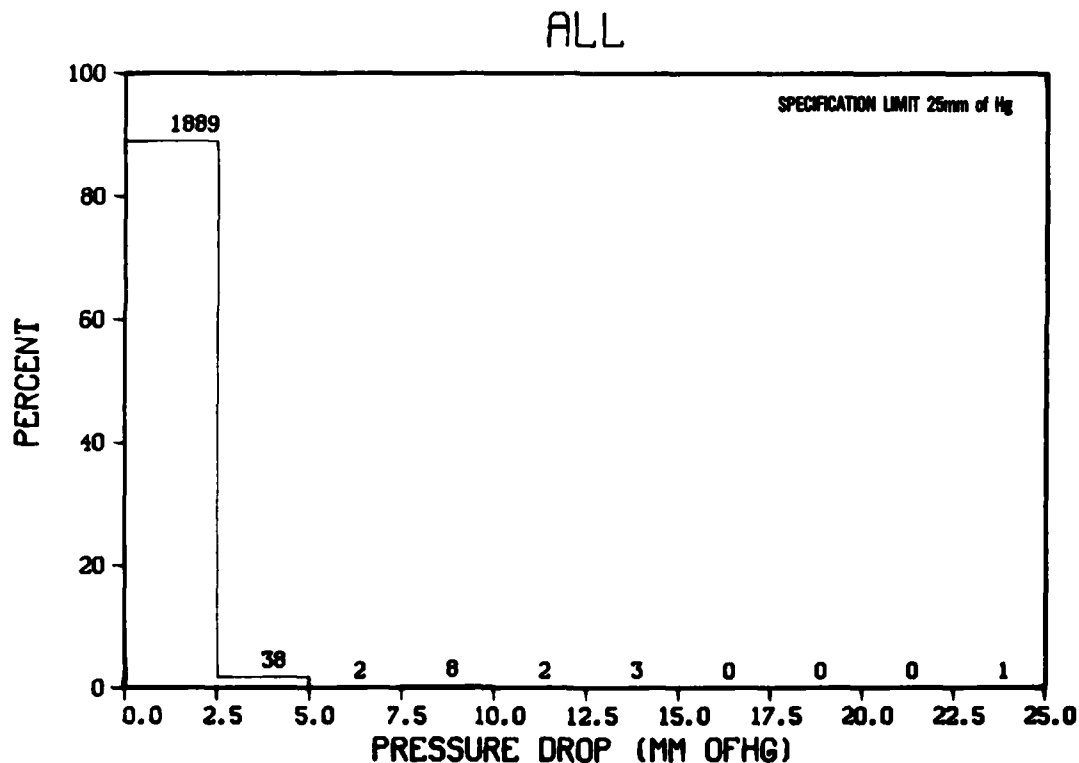


Figure 74. Thermal Stability Change in Pressure Drop Variations: Worldwide

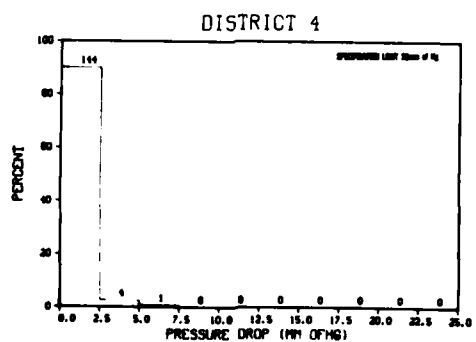
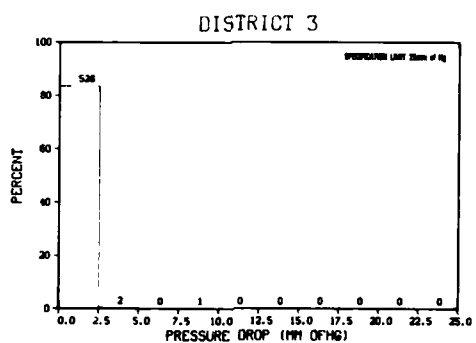
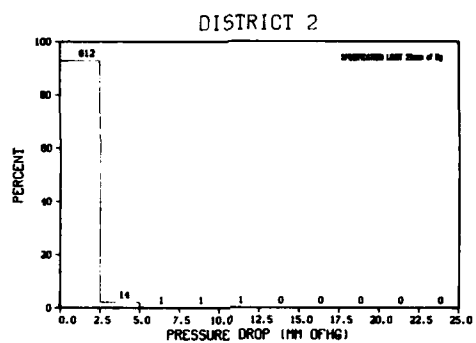
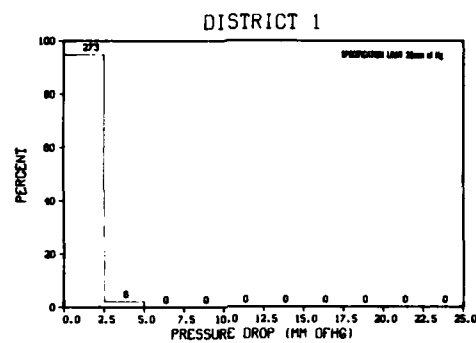


Figure 75. (a-d) Thermal Stability Change in Pressure Drop Variations: Districts 1 - 4

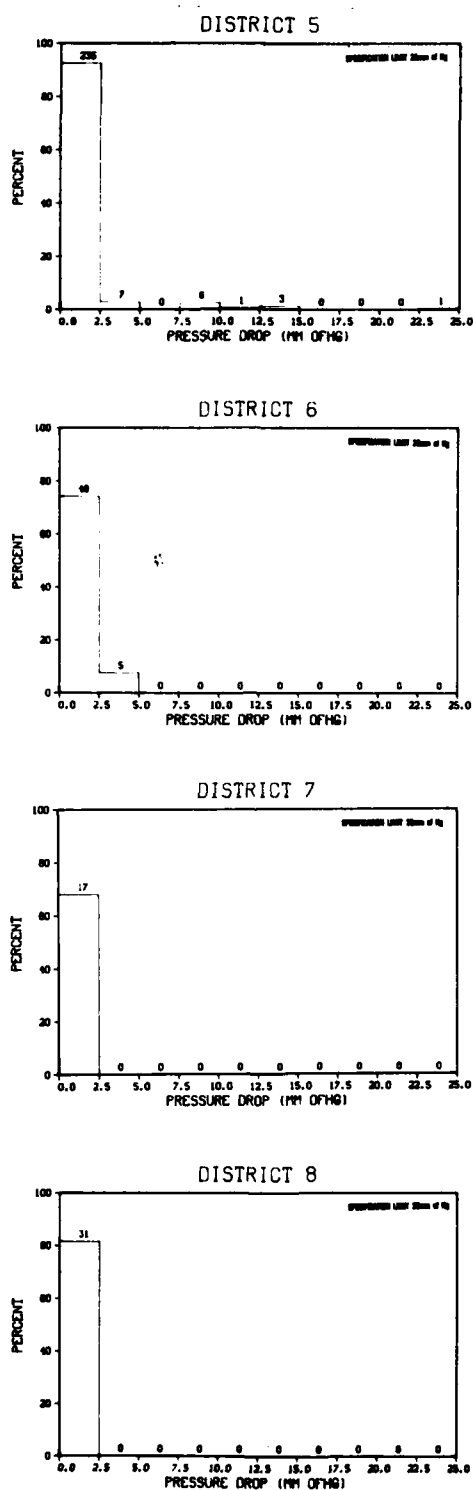


Figure 75. Continued (e-h) Thermal Stability Change in Pressure Drop Variations: Districts 5 - 8

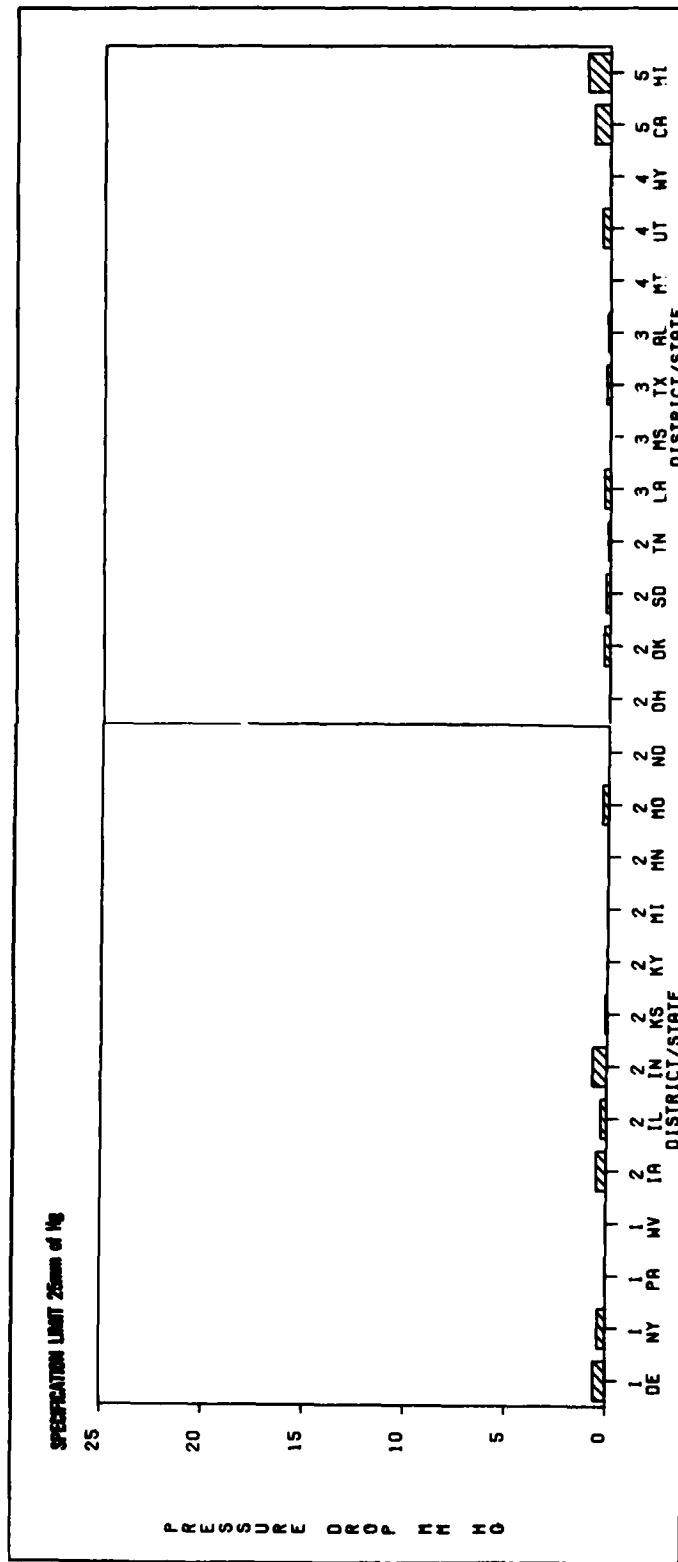


Figure 76. Thermal Stability Change in Pressure Drop Variations:
States

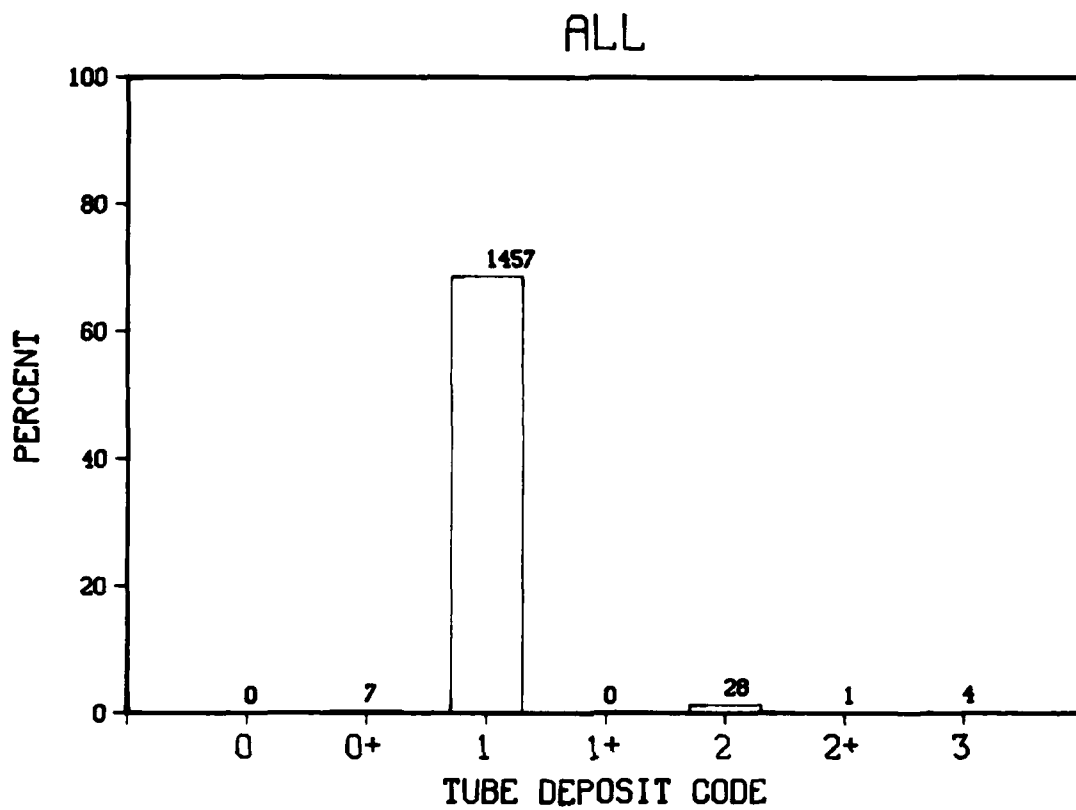


Figure 77. Thermal Stability Tube Deposit Code Variations: Worldwide

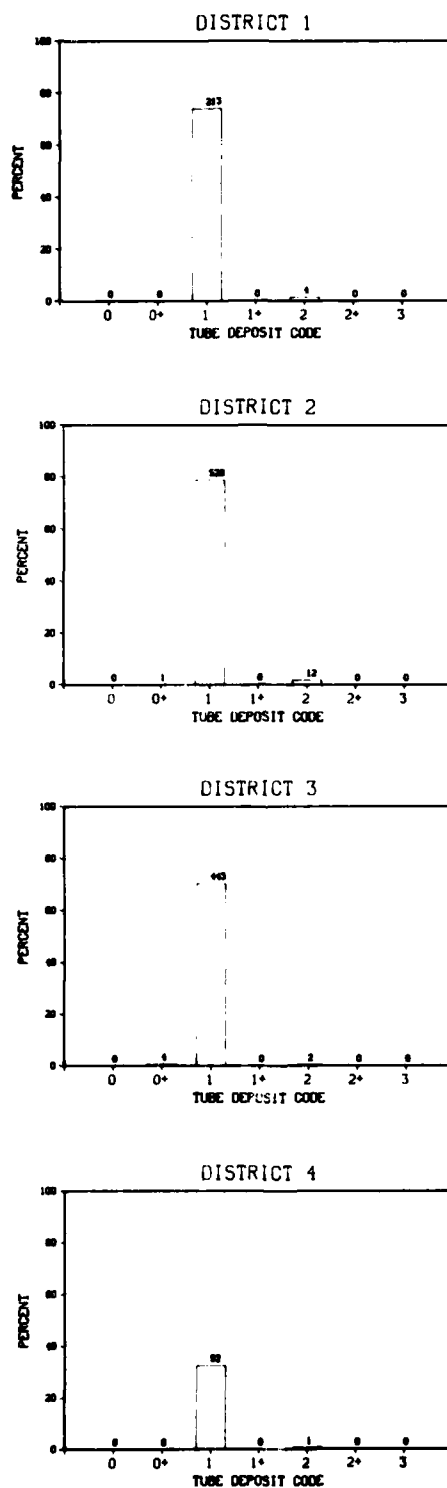


Figure 78. (a-d) Thermal Stability Tube Deposit Code Variations: Districts 1 - 4

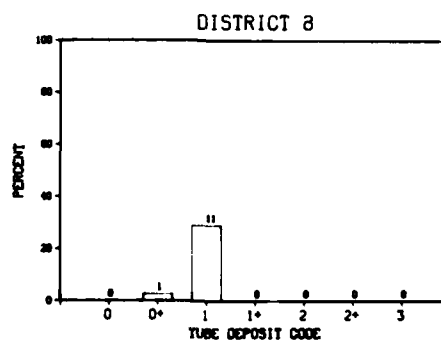
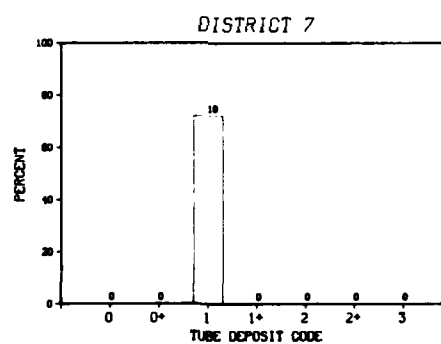
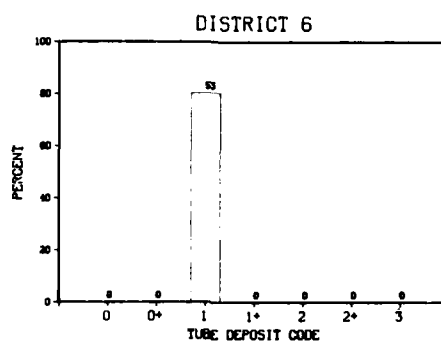
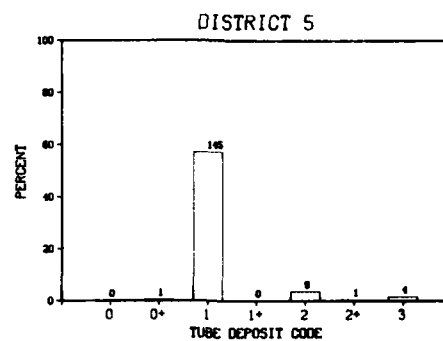


Figure 78. Continued (e-h) Thermal Stability Tube Deposit Code Variations: Districts 5 - 8

14. EXISTENT GUM

The "average" existent gum varies between 0.0 and the specification limit of 7.0mg/100ml worldwide. Most of the samples had an existent gum of less than 3.5mg/100ml. These values are consistent among districts and across the states within the CONUS. The "average" existent gum worldwide was 0.8mg/100ml. Within the United States, fuels from Kansas and Alabama had the lowest "average" existent gum of 0.2mg/100ml; fuels from Illinois had the highest "average" existent gum of 1.7mg/100 ml. The "near specification limit" for this test is 2.0mg/100ml. Approximately four percent of the samples fall in this "near specification band."

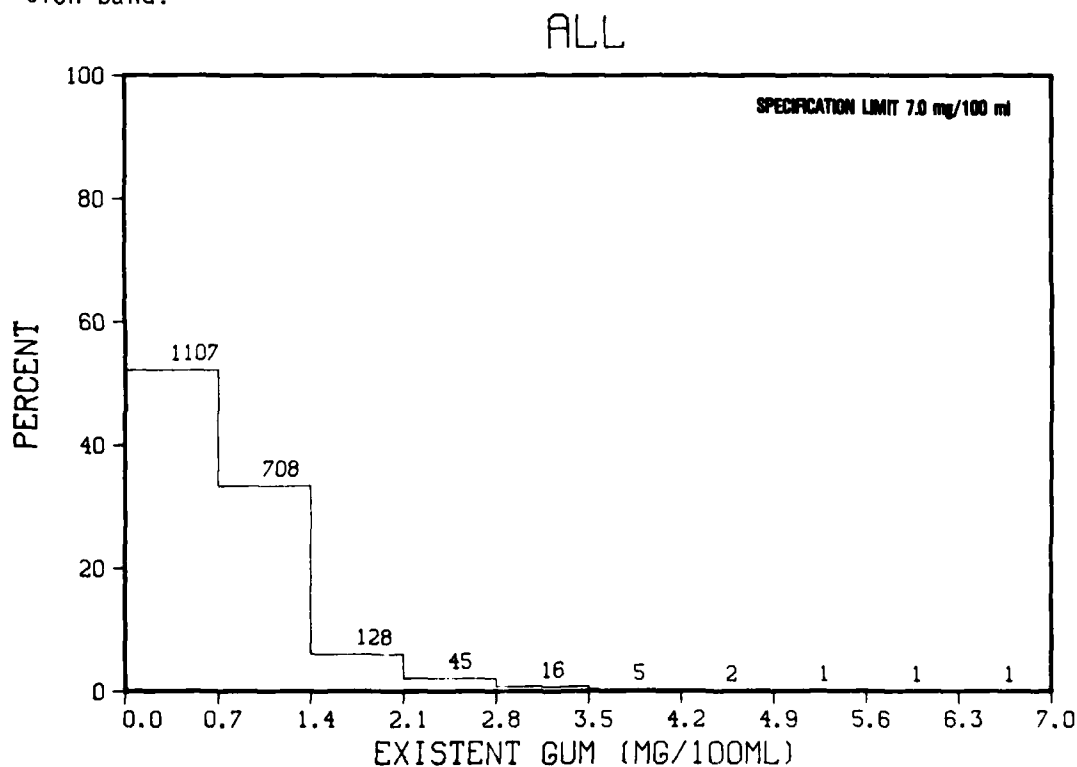


Figure 79. Existent Gum Variations: Worldwide

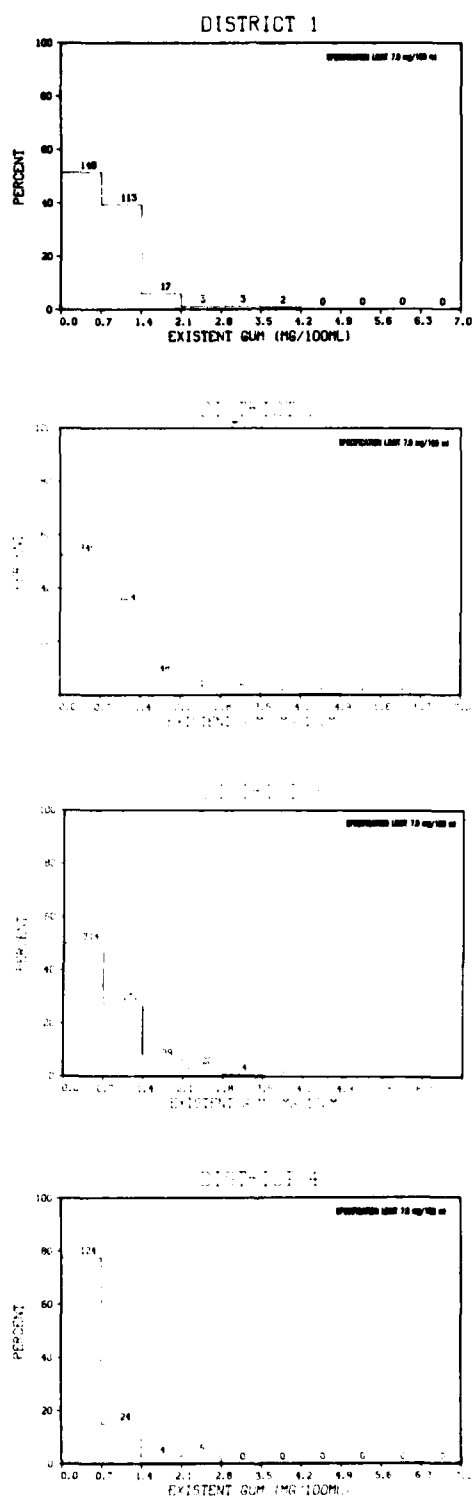


Figure 80. (a-d) Existent Gum Variations: Districts 1 - 4

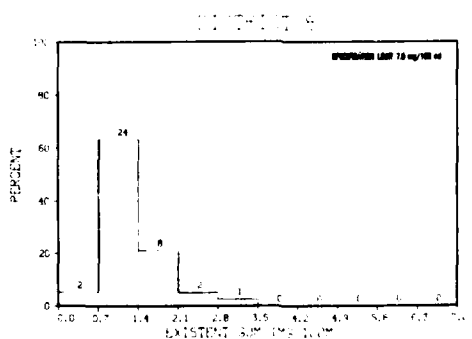
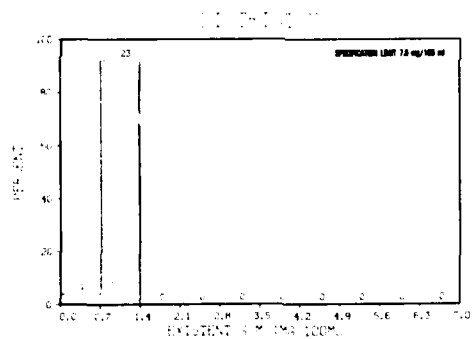
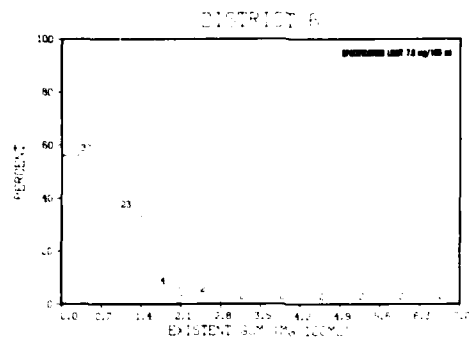
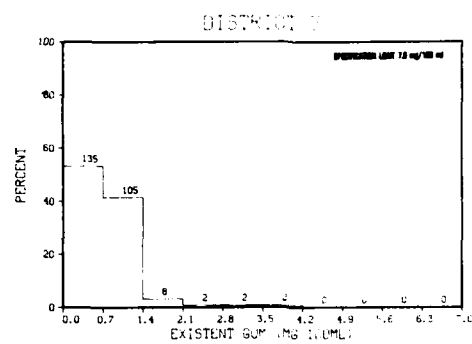


Figure 80. Continued (e-h) Existent Gum Variations: Districts 5 - 8

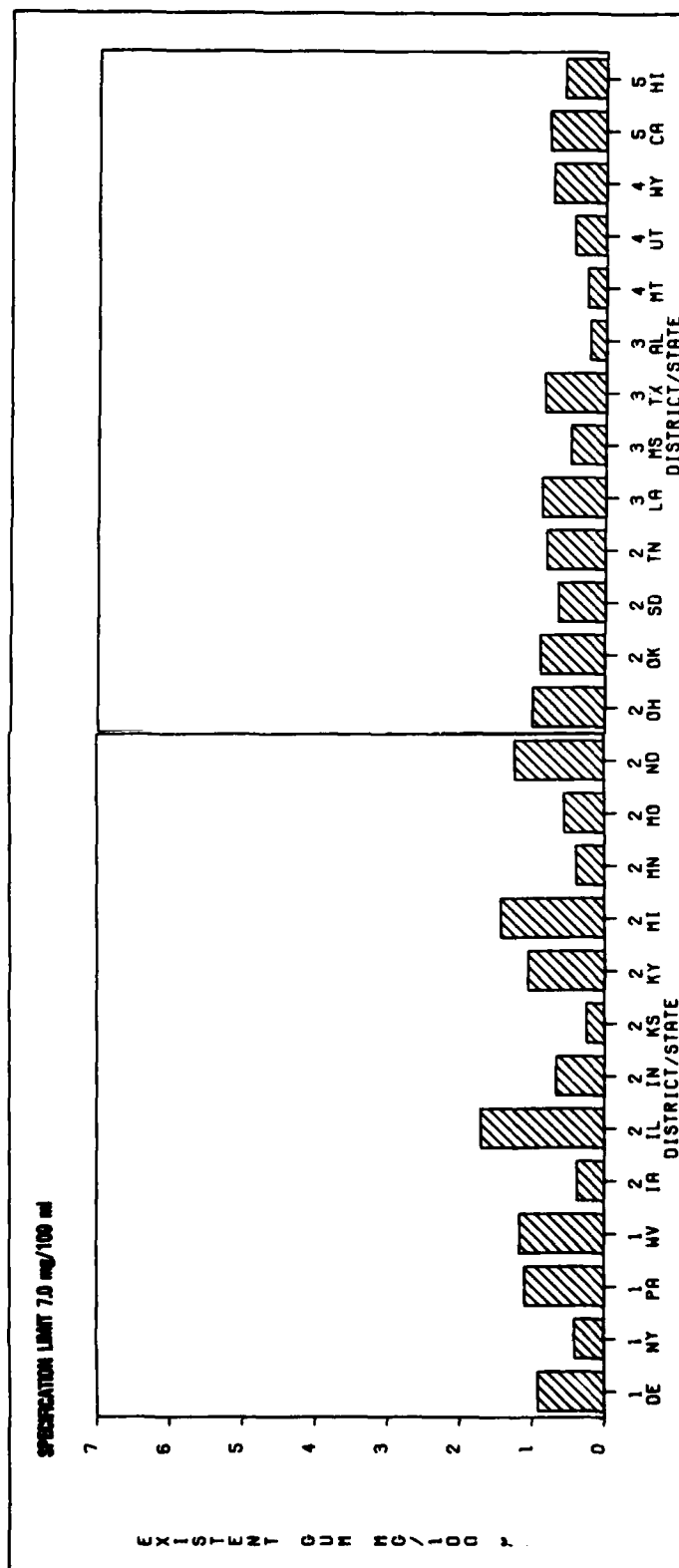


Figure 81. Existing Gum Variations: States

15. PARTICULATE MATTER

The particulate matter in JP-4 varies between 0.0 and the specification limit of 1.0mg/l. Variations existed among districts and between the states which comprise Districts 1 through 8. The "average" value for particulate matter worldwide was 0.4mg/l. Within the CONUS, fuels from Kansas and Alabama had the lowest "average" particulate matter contamination of 0.2mg/l; fuels from Pennsylvania, Illinois, and Missouri had the highest "average" particulate matter contamination of 0.6 mg/l. The "near specification limit" for this test is 0.38mg/l. Less than 44 percent of the samples fell within the "near specification band."

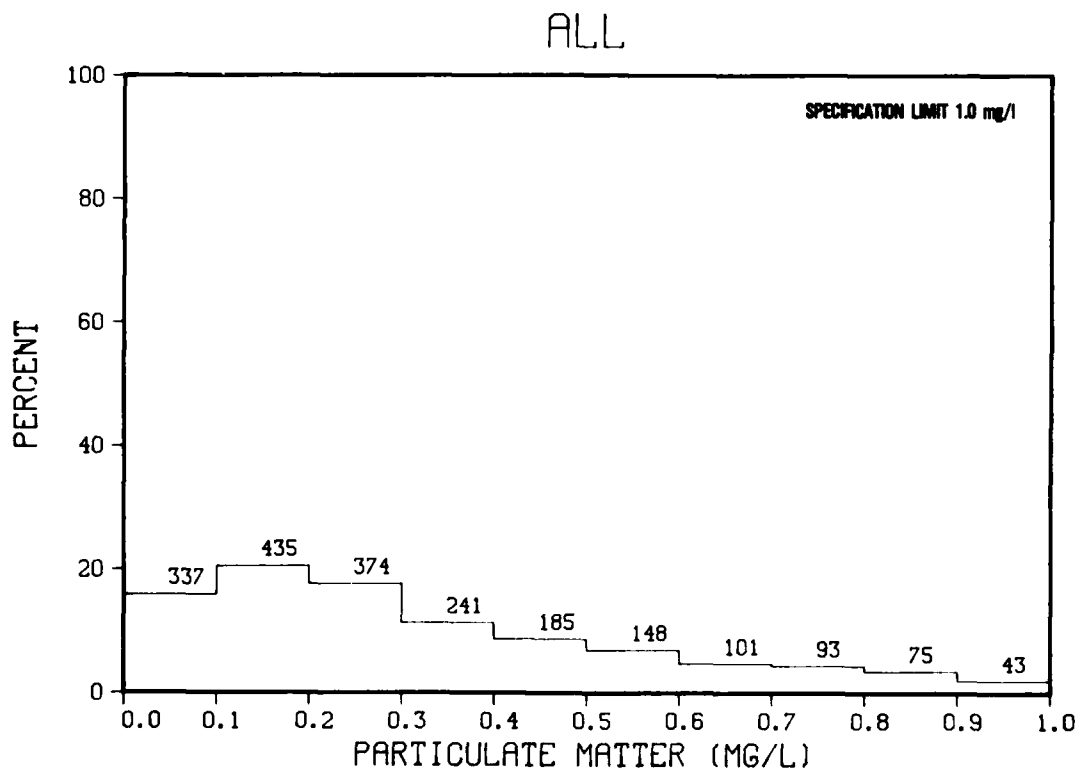


Figure 82. Particulate Matter Variations: Worldwide

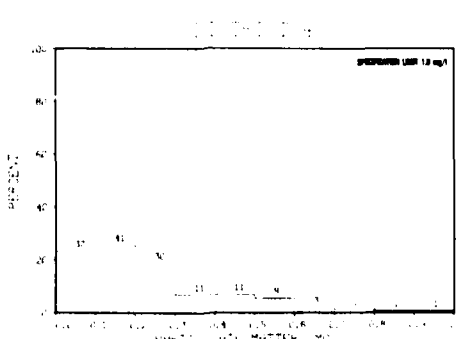
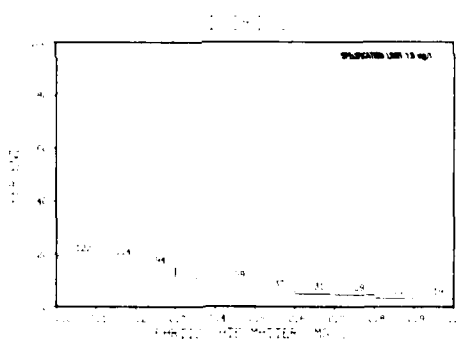
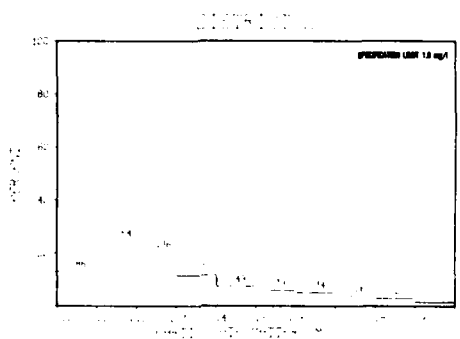
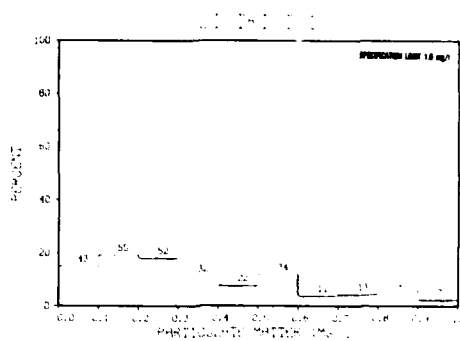


Figure 83. (a-d) Particulate Matter Variations: Districts 1 - 4

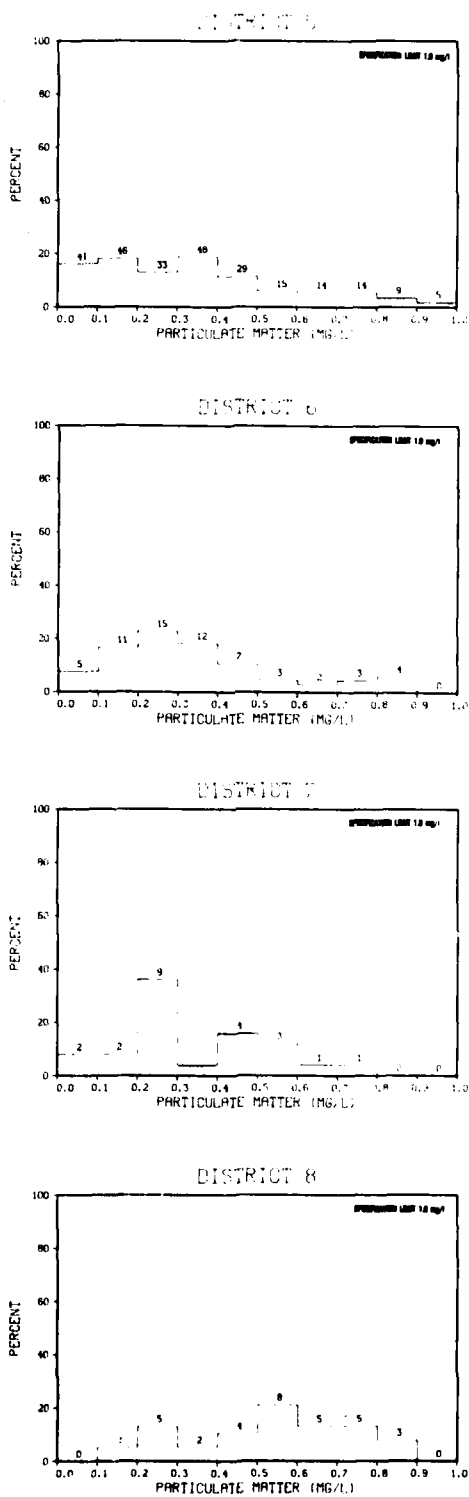


Figure 83. Continued (e-h) Particulate Matter Variations: Districts 5 - 8

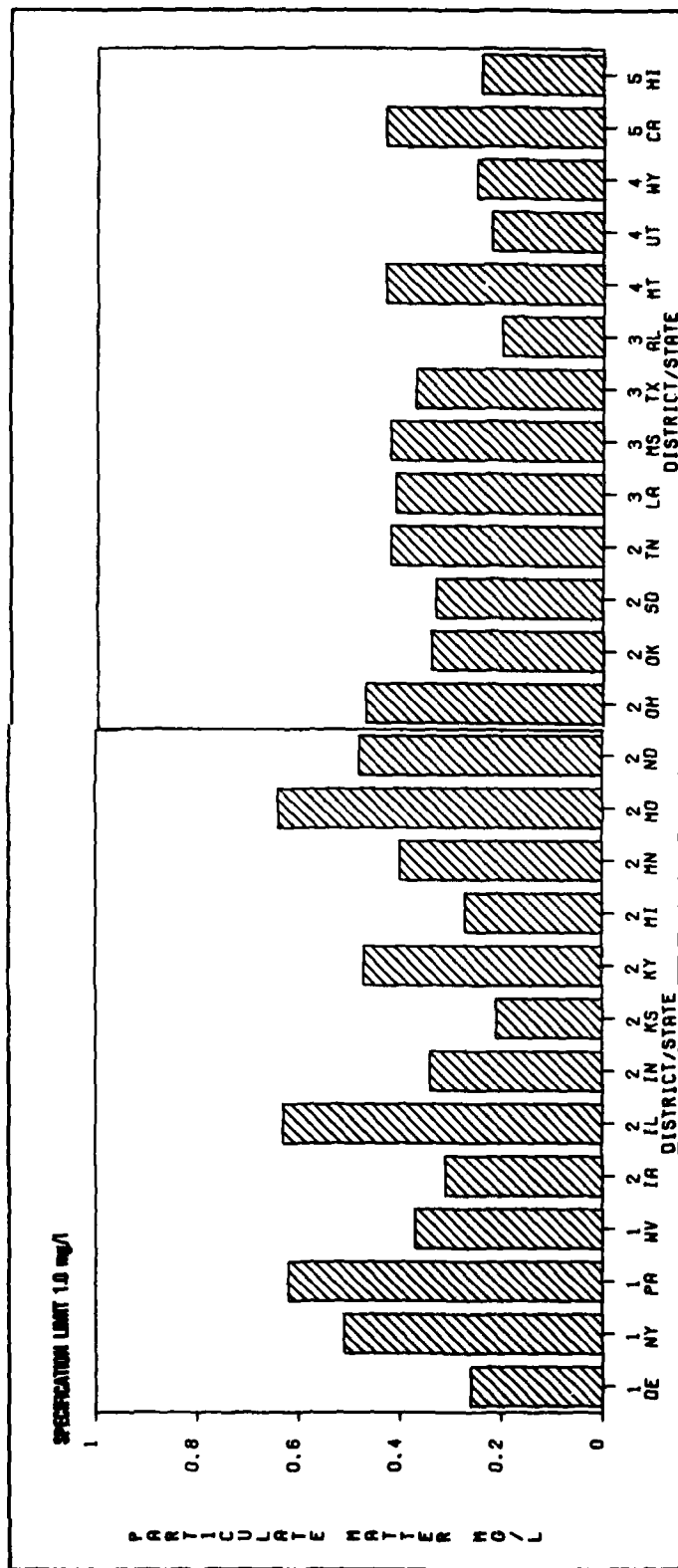


Figure 84. Particulate Matter Variations: States

16. WATER SEPARATION INDEX MODIFIED

The water separation index modified (WSIM) test data varied from the specification limit of 70 to 100. Variations existed among districts worldwide and among states within the CONUS. The "average" WSIM value worldwide was 87. Within the CONUS, fuels from Wyoming had the lowest "average" WSIM of 79; fuels from West Virginia had the highest "average" WSIM of 97. The "near specification limit" for this test was 90. Approximately 64 percent of the fuel samples fell within this "near specification band."

The WSIM test has a minimum of 85 if the fuel was tested with all the additives present except for corrosion inhibitor and the electrical conductivity additive. The minimum WSIM was 70 if the fuel was tested with all additives present except the electrical conductivity additive. Some of the refiners in Districts 2 and 3 perform the WSIM test without the above mentioned additives. Samples from these refiners have WSIM values between the specification limit of 85 and 100. The near specification limit for this test is 95. Approximately 35 percent of these samples fell within this "near specification band."

ALL

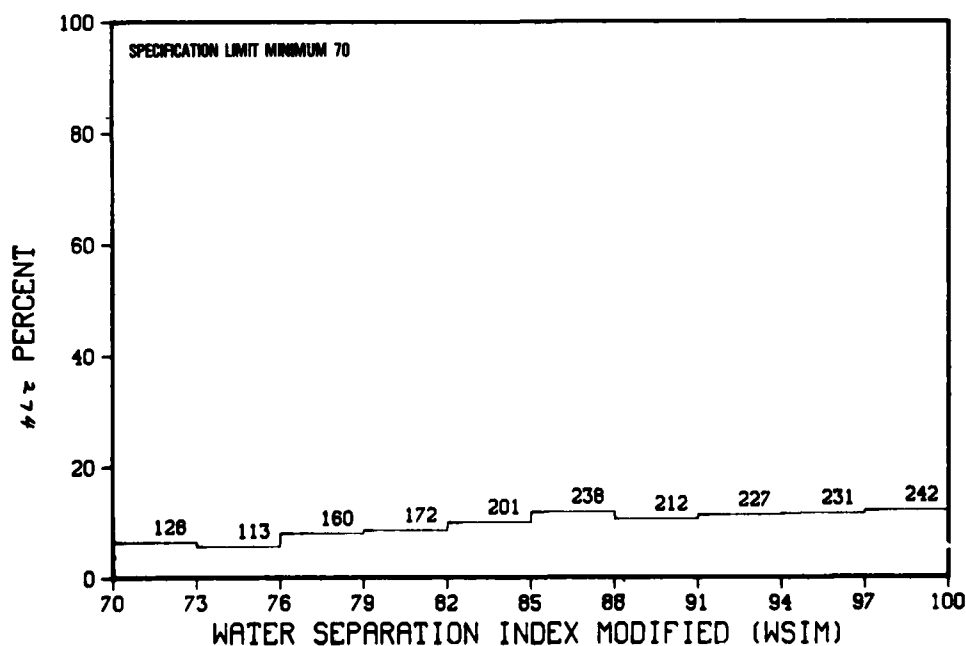


Figure 85. WSIM Variations: Worldwide

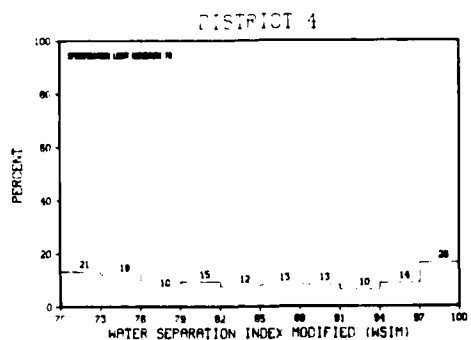
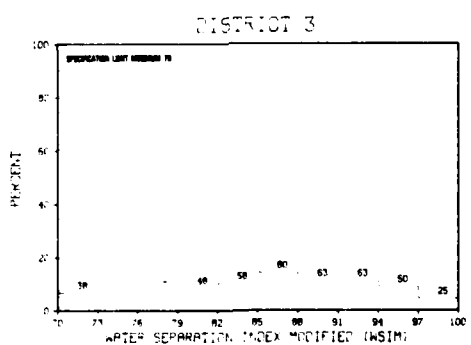
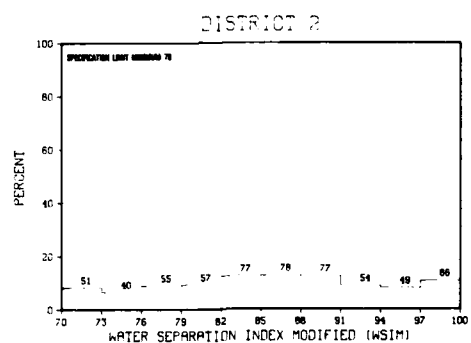
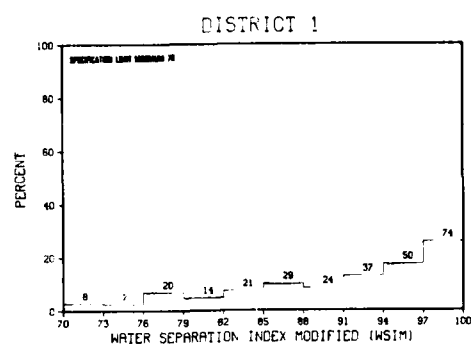


Figure 86. (a-d) WSIM Variations: Districts 1 - 4

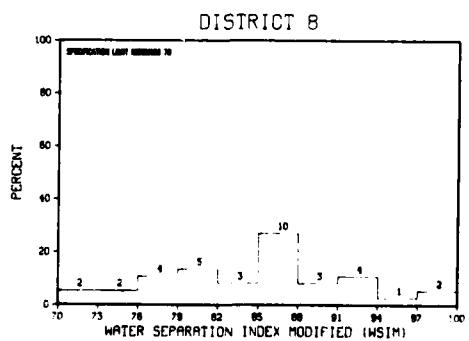
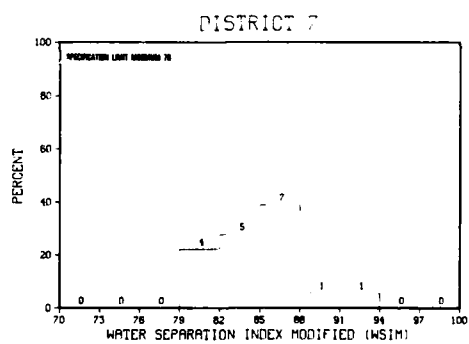
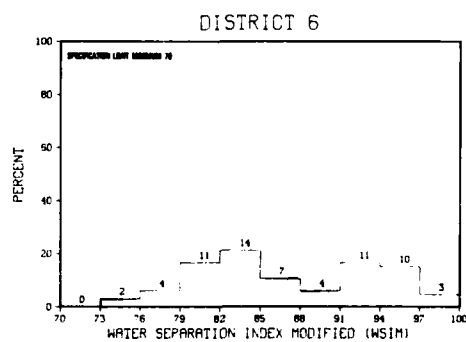
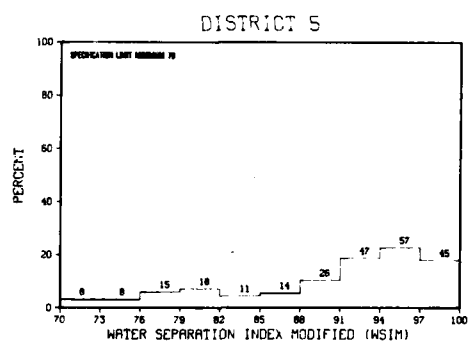


Figure 86. Continued (e-h) WSIM Variations: Districts 5 - 8

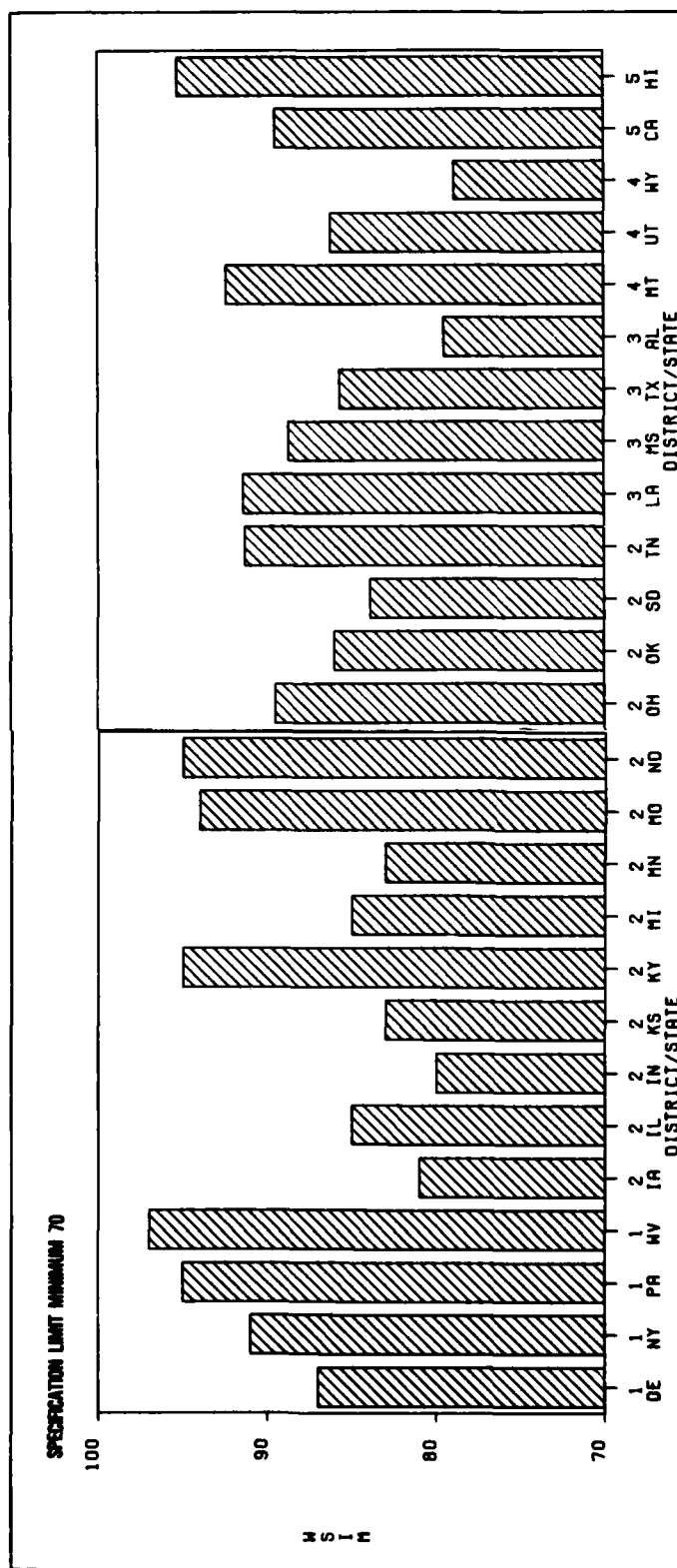


Figure 87. WSIM Variations: States

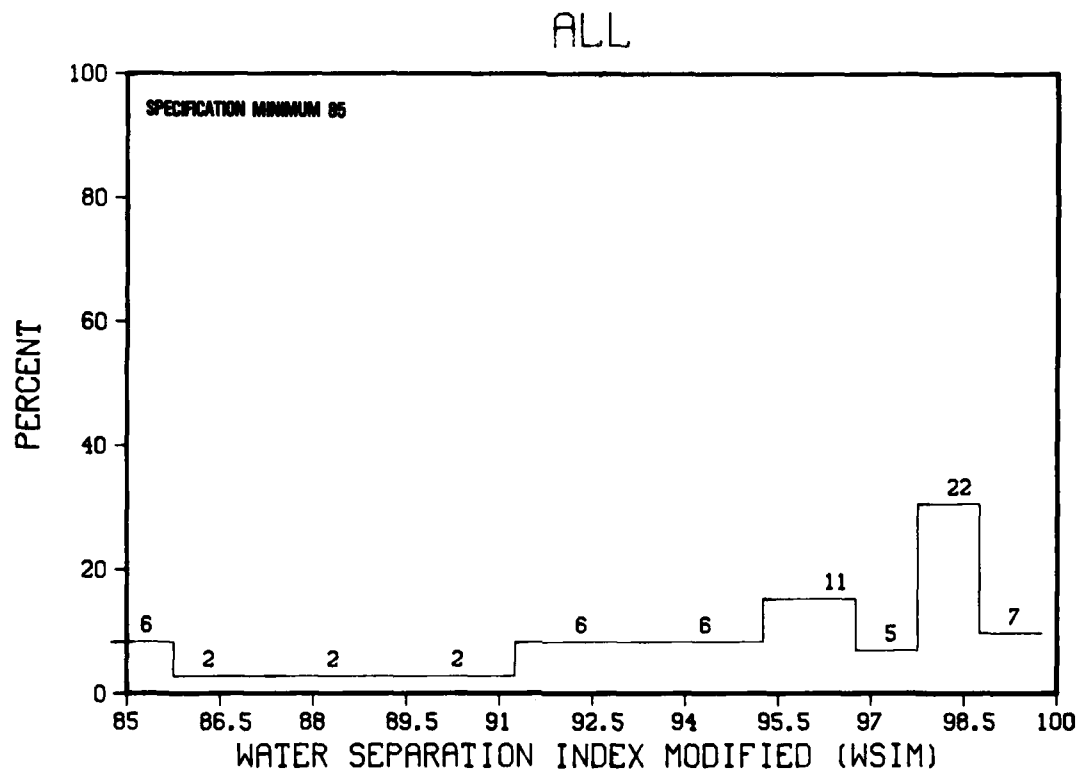


Figure 88. WSIM Variations: Worldwide

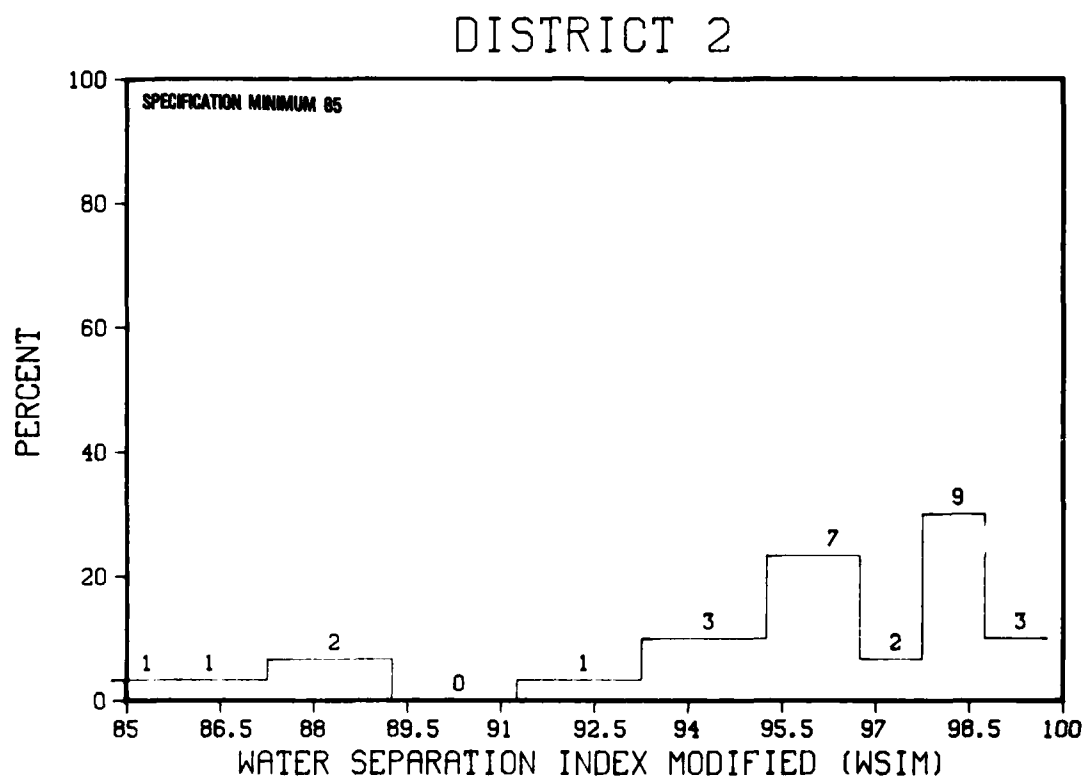


Figure 89. WSIM Variations: District 2

DISTRICT 3

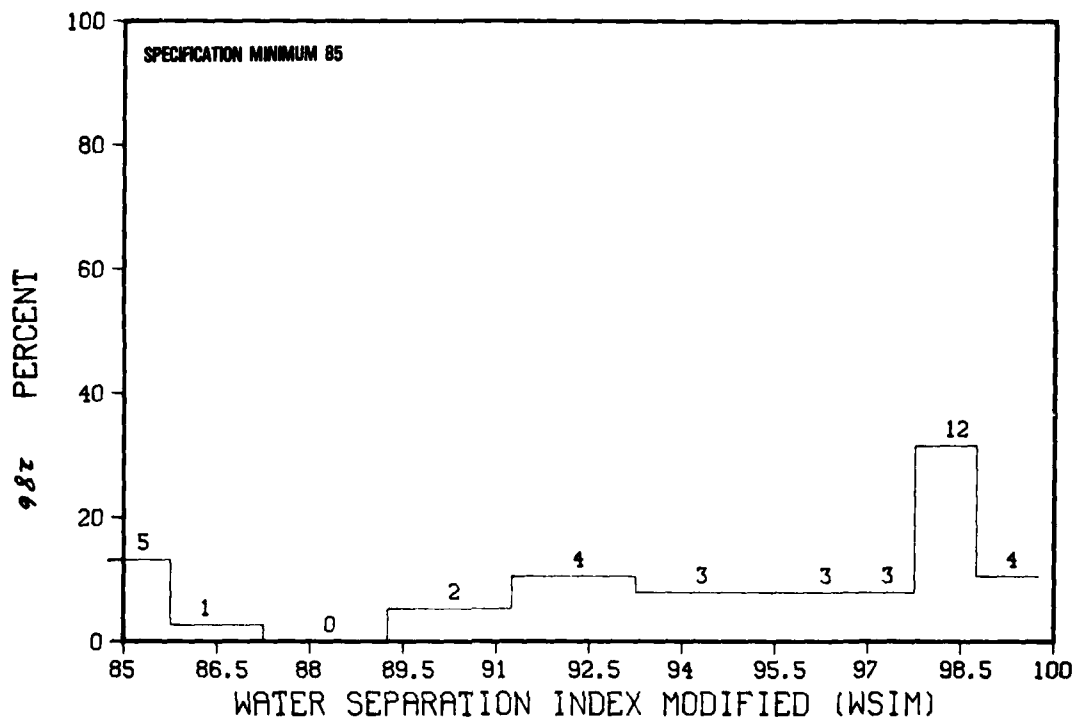


Figure 90. WSIM Variations: District 3

17. VOLUME PERCENT ICING INHIBITOR

The volume percent icing inhibitor varies from 0.0 to 0.15 volume percent worldwide. The specification lower and upper limits are 0.10 and 0.15 volume percent respectively. However, 15 percent of the lots of JP-4 contained less icing inhibitor than the specification lower limit. Icing inhibitor does not have to be added at the refinery if other arrangements are made by the refiner to add the icing inhibitor before delivery. The volume percent icing inhibitor varies from district to district and from state to state within the CONUS. The "average" volume percent icing inhibitor worldwide was 0.13 volume percent. It should be noted that the values for states that are less than the lower specification limit may be influenced by fuels that did not have icing inhibitor added since it was added at a later time. Also, some refiners that ship fuel by barge or by tanker may add icing inhibitor in excess to the upper specification limit since some of the icing inhibitor is leached into the water bottoms of the tanks.

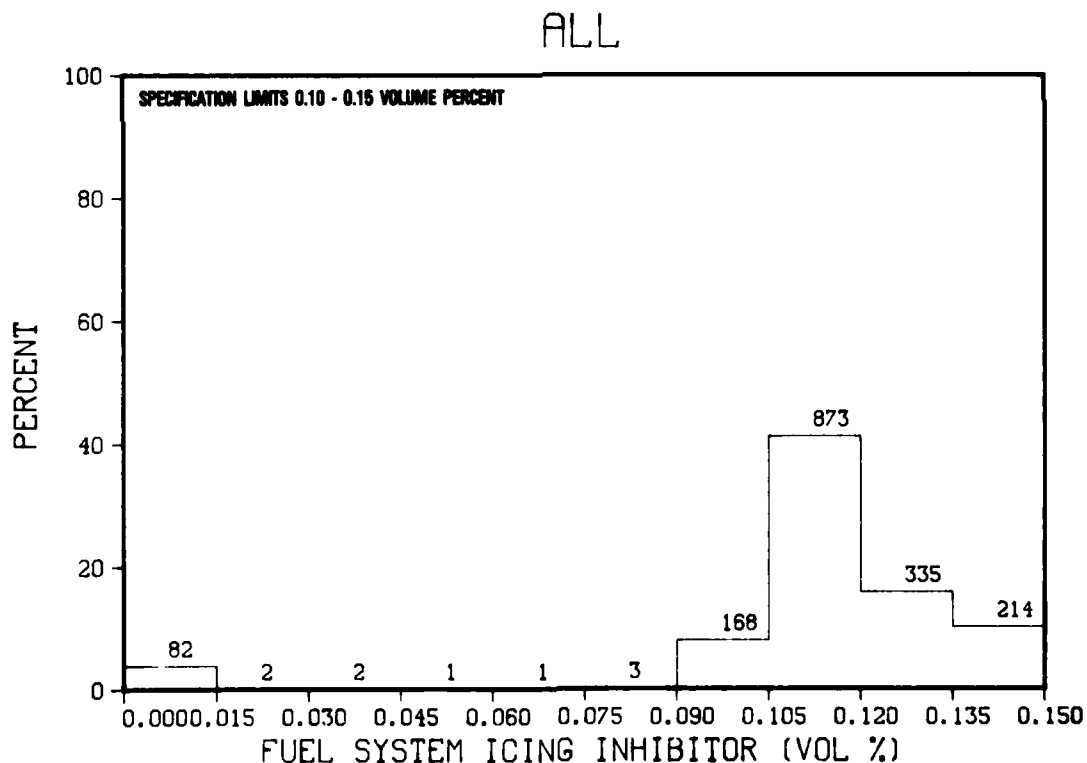


Figure 91. Volume Percent Fuel System Icing Inhibitor Variations: Worldwide

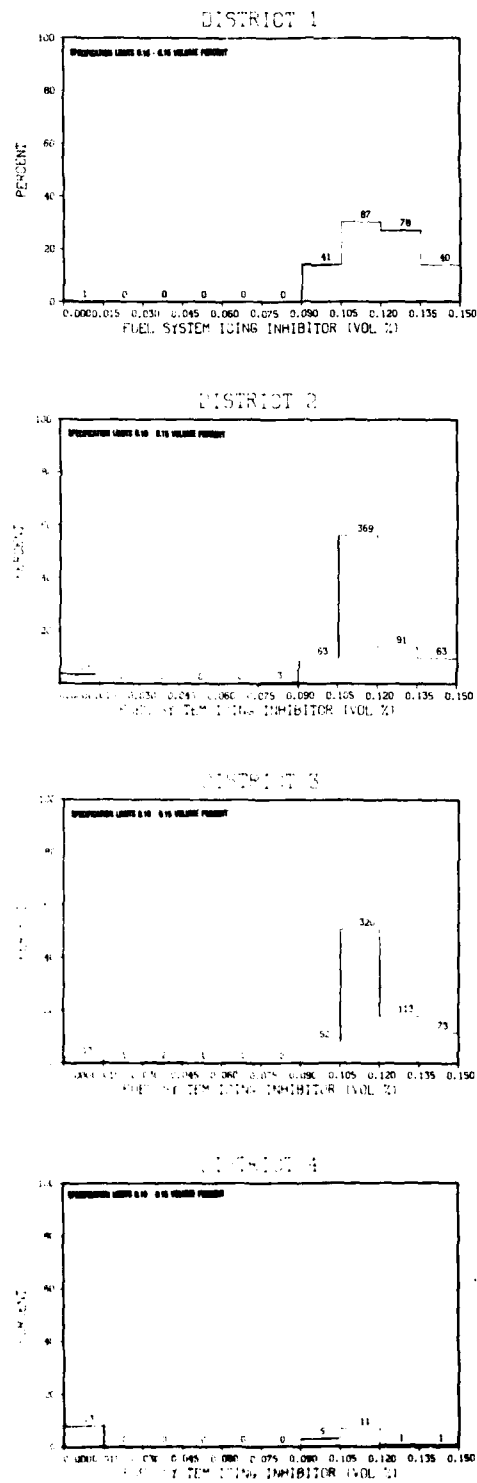


Figure 92. (a-d) Volume Percent Fuel System Icing Inhibitor Variations: Districts 1 - 4

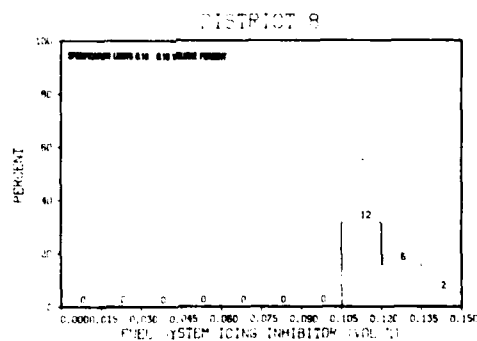
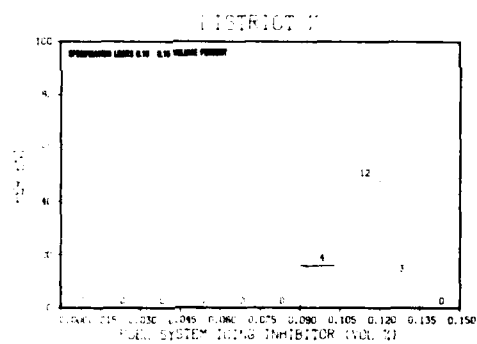
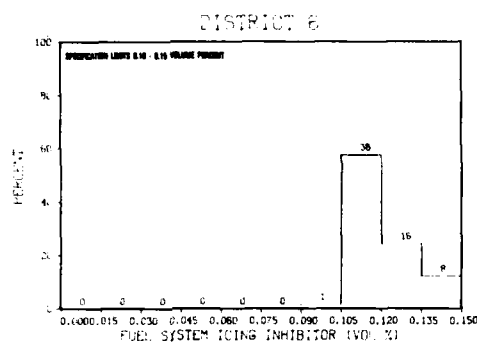
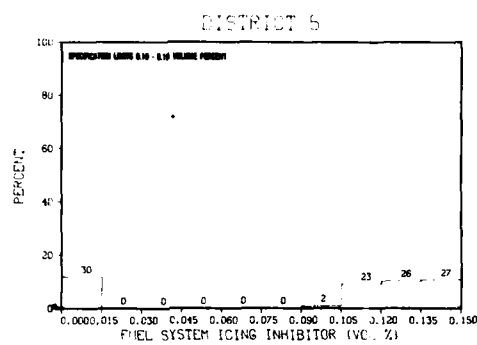


Figure 92. Continued (e-h) Volume Percent Fuel System Icing Inhibitor Variations: Districts 5 - 8

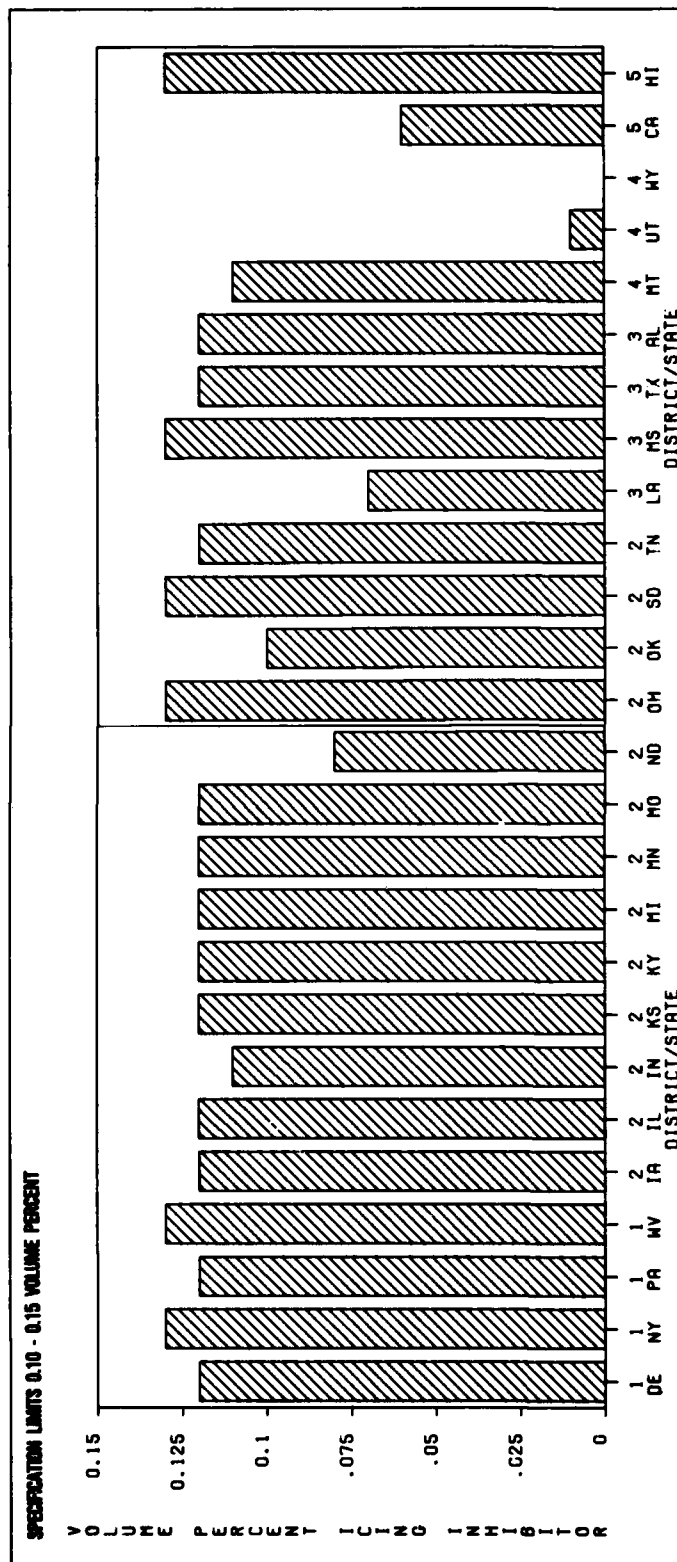


Figure 93. Volume Percent Fuel System Icing Inhibitor Variations: States

18. FUEL ELECTRICAL CONDUCTIVITY

The fuel electrical conductivity additive and measurement for this additive were phased in during the reporting period of this report. Only 77 samples were tested for electrical conductivity and the "average" electrical conductivity of these samples was 325 pS/m.

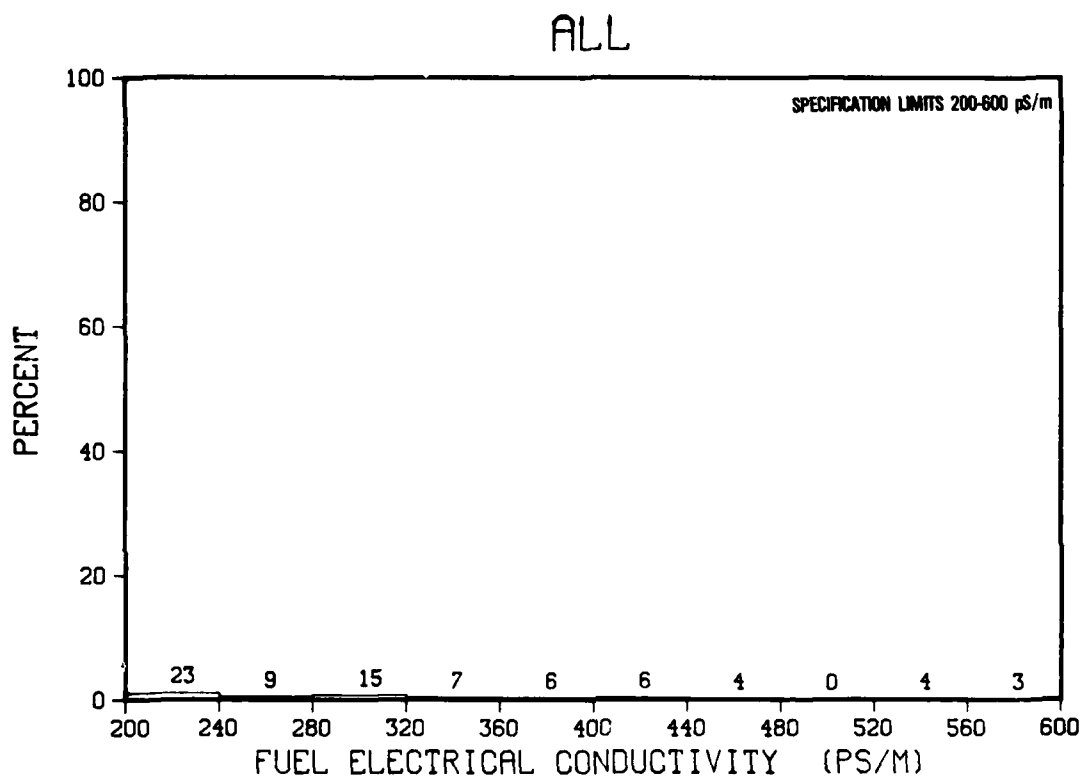


Figure 94. Fuel Electrical Conductivity Variations: Worldwide

19. ANTIOXIDANTS

The data were sampled to determine the percentage of JP-4 which had antioxidants added. The refiners are required to add antioxidants to batches of JP-4 that contain hydrogen treated blending stocks and may add antioxidants to other JP-4 batches. Antioxidants were added to 48 percent of the samples. Variations existed among districts; for example, District 7 contained no samples with antioxidants while in District 8, 95 percent of the samples contained antioxidants. Within the CONUS, over 90 percent of the JP-4 samples from Delaware, Pennsylvania, West Virginia, Iowa, Illinois, Kentucky, and North Dakota contained antioxidants. Fuels from New York, Kansas, Louisiana, and Missouri did not contain antioxidants.

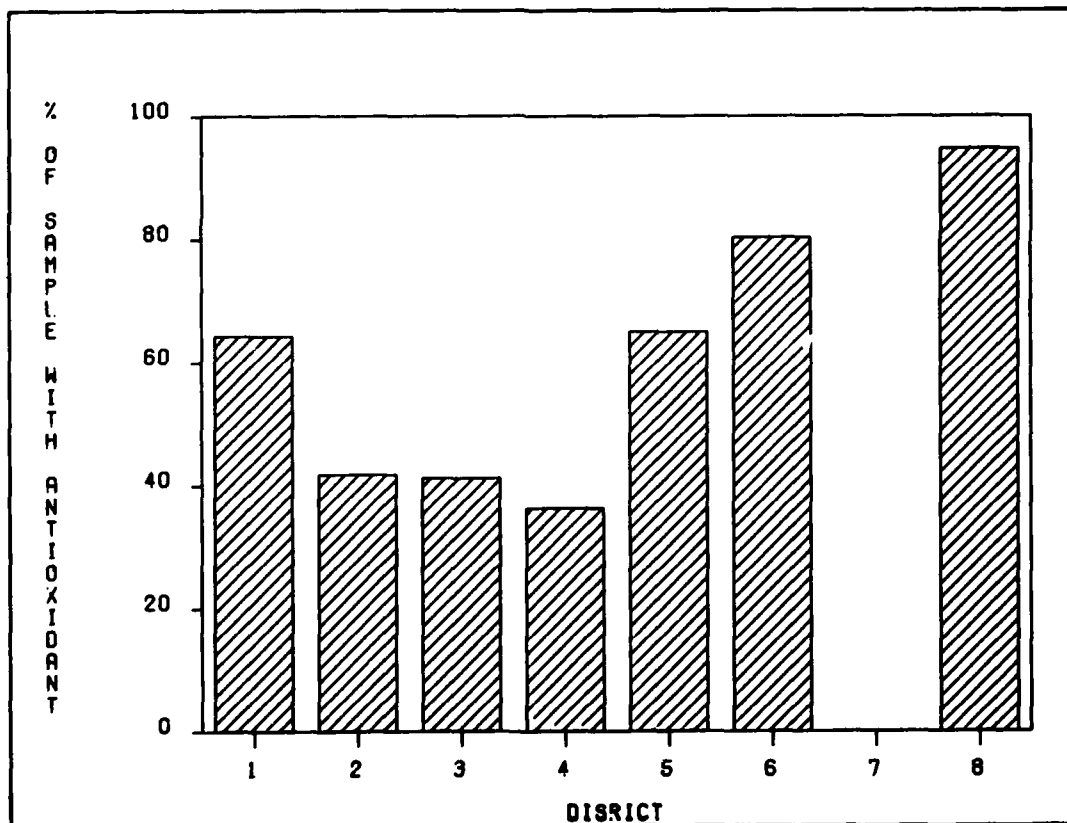


Figure 95. Total Percent of Fuel Lots which Contain Antioxidants: Districts

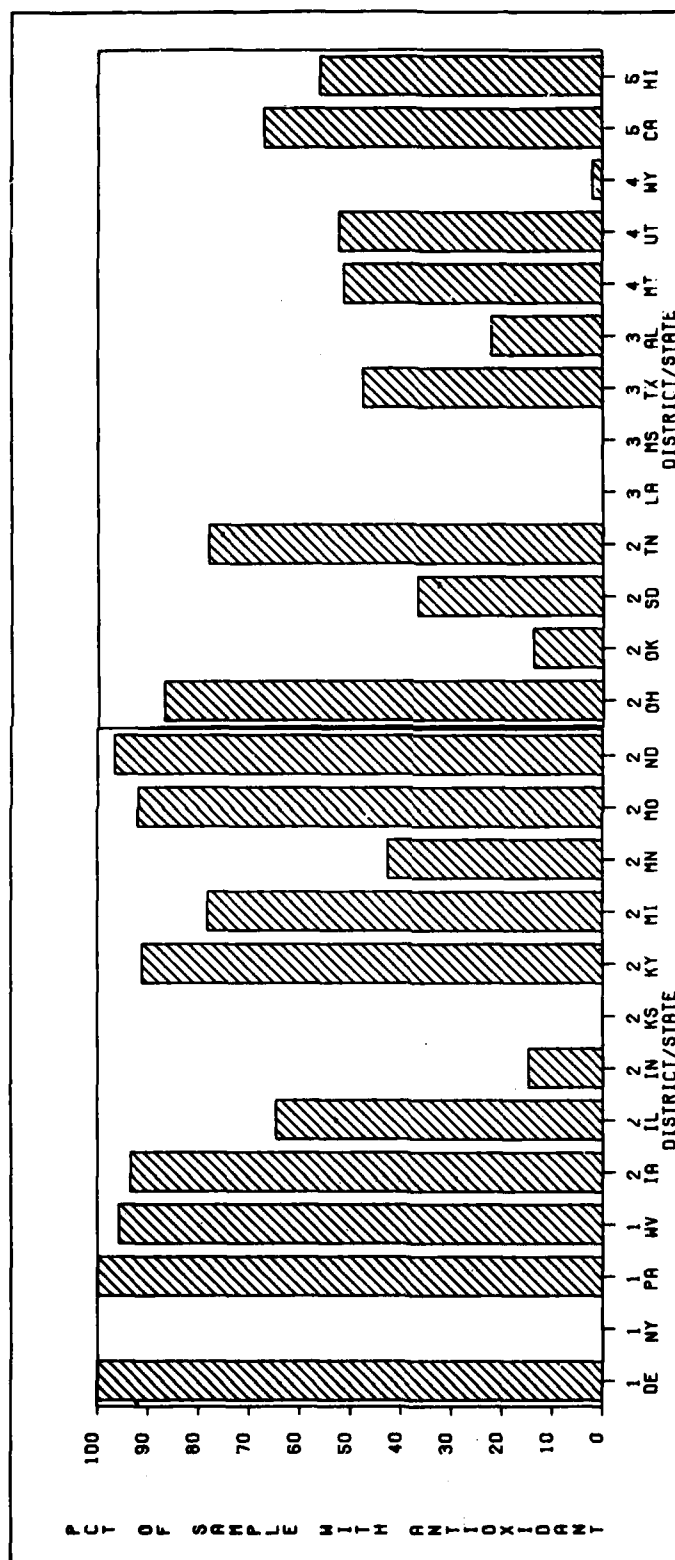


Figure 96. Total Percentage of Fuel Lots which Contain Antioxidants:
States

20. SEASONAL VARIATIONS IN JP-4

This section of the report will investigate whether or not seasonal variations exist in JP-4. It has been thought that seasonal variations might exist since, historically, the refiners' maximize gasoline production in the summer and maximize home heating oil production in the winter. These production changes would likely be seen in the JP-4 pool. The existence of seasonal variation was discussed with a refiner. Many refiners produce JP-4 from a naphtha cut blended with a 20 to 40 percent kerosene cut. There should be little seasonal differences in the lower boiling components in JP-4 since the naphtha stream does not change significantly, though in the winter less fuel is cracked and reformed. The higher boiling range would change since some of the kerosene cut material would be blended into the home heating oil pool. Time lags in production were also discussed. It had been thought that possible variation may exist several months prior to summer or winter. In general though, the refiner will build up inventories of gasoline or home heating oil to meet the demand for the season, then maximize the production of these materials when the demand is greatest.

To verify these assumptions and investigate the existence or non-existence of seasonal variations, plots of boiling range distribution worldwide were drawn. Plots included are for D 86 distillation initial boiling point, 10, 20, 50, and 90 percent recovered and the final boiling point. The data for the initial boiling point, 10 and 20 percent recovered are relatively constant over the report period, however, differences between districts exist. For example, the ten percent recovered temperature from District 1 (East Coast) is much lower than any other district. If there was a difference in the gasoline product slate (lower boiling components), seasonal changes would be visible for these above properties. The data illustrates no differences.

Differences in boiling range for the 50, 90, and end point D 86 distillation are rather large between districts. Seasonal variations in the production of home heating oil would be seen in these boiling ranges though. In District 1 (East Coast), District 2 (Midwest), and District 5 (Pacific), there is a general trend toward lower boiling temperatures

for the above mentioned test for the months of December through March. This is consistent with the discussions with the refiner. During these months (December through March), the demand for home heating oil is high and stocks that had been built up during the year would be drawing down.

To further investigate seasonal variations, five states were chosen as being representative of the district in which they are located. The states chosen are Pennsylvania (combined with data from Delaware to give a statistically larger sample)(District 1 - East Coast), Indiana (District 2 - Midwest), Texas (District 3 - South), Utah (District 4 - Rocky Mountain), and California (District 5 - Pacific). The following properties were investigated: API gravity, smoke point, volume percent aromatics, hydrogen content, and D 86 distillation 50, 90 percent recovered and end point. No significant seasonal trends could be discerned though large variations exist between the states.

The above data reveals little seasonal variation in JP-4 with the possible exception of a slight decrease in the higher boiling components between December and March. In general, JP-4 does not change significantly during the year but differences exist due to crude sources and refining schemes.

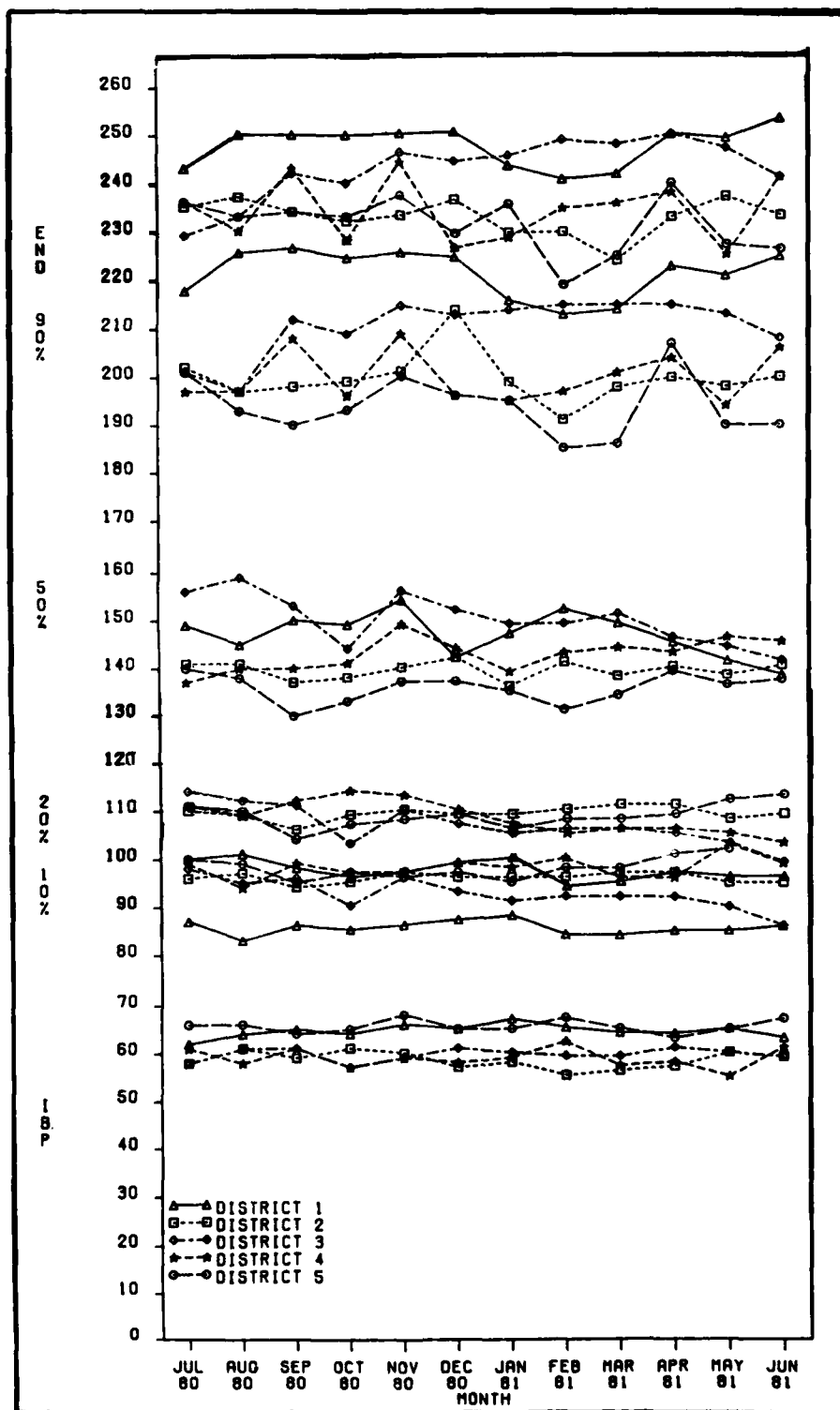


Figure 97. Boiling Range Distribution by D 86 Distillation:
Seasonal Trends

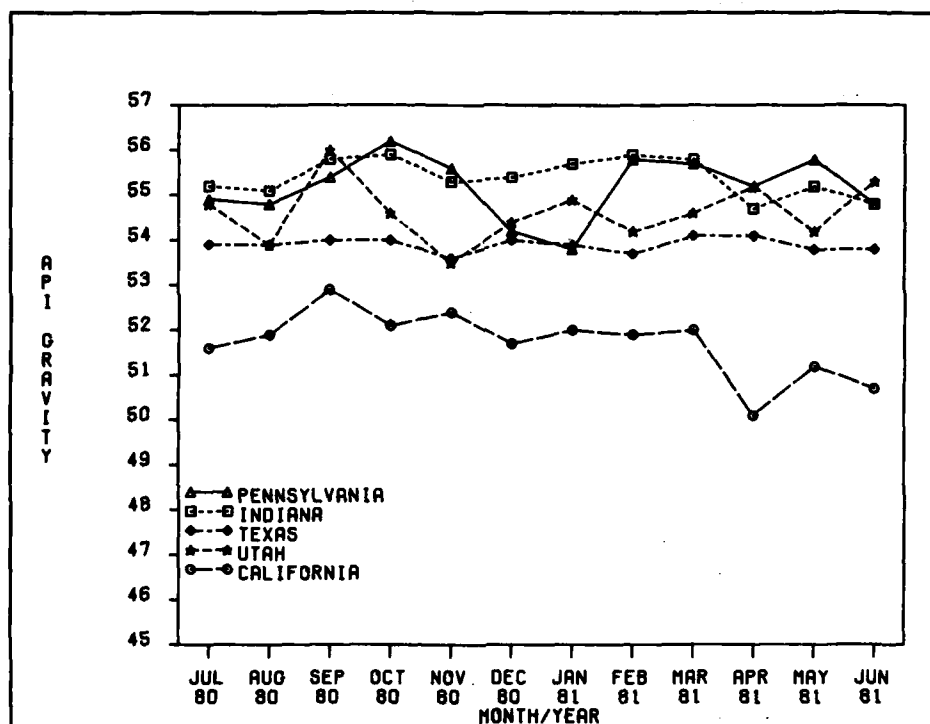


Figure 98. API Gravity: Seasonal Trends

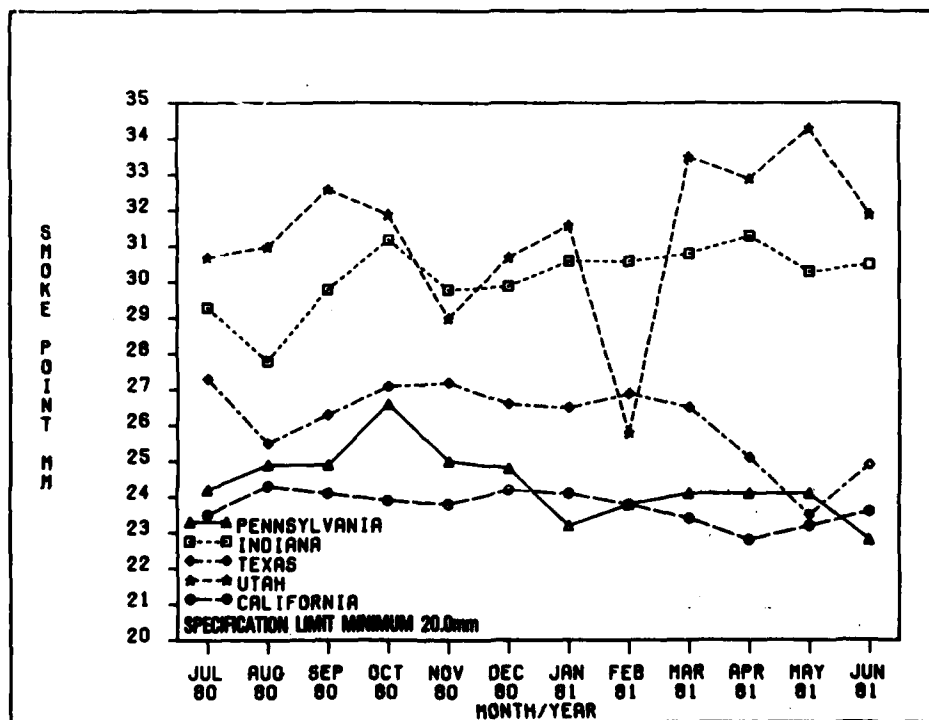


Figure 99. Smoke Point: Seasonal Trends

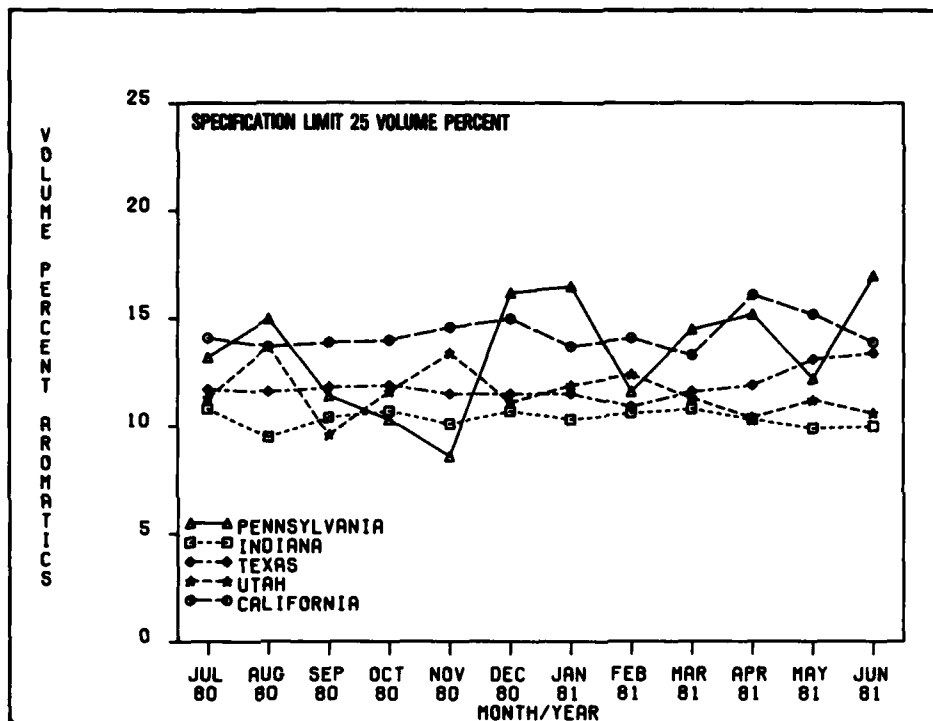


Figure 100. Volume Percent Aromatics: Seasonal Trends

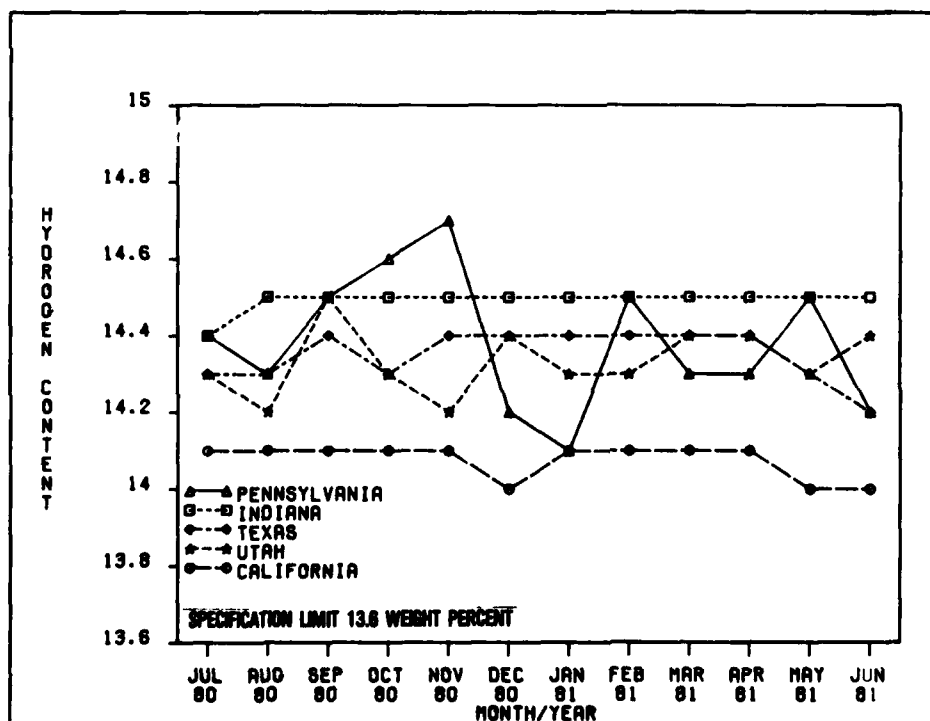


Figure 101. Volume Percent Aromatics: Seasonal Trends

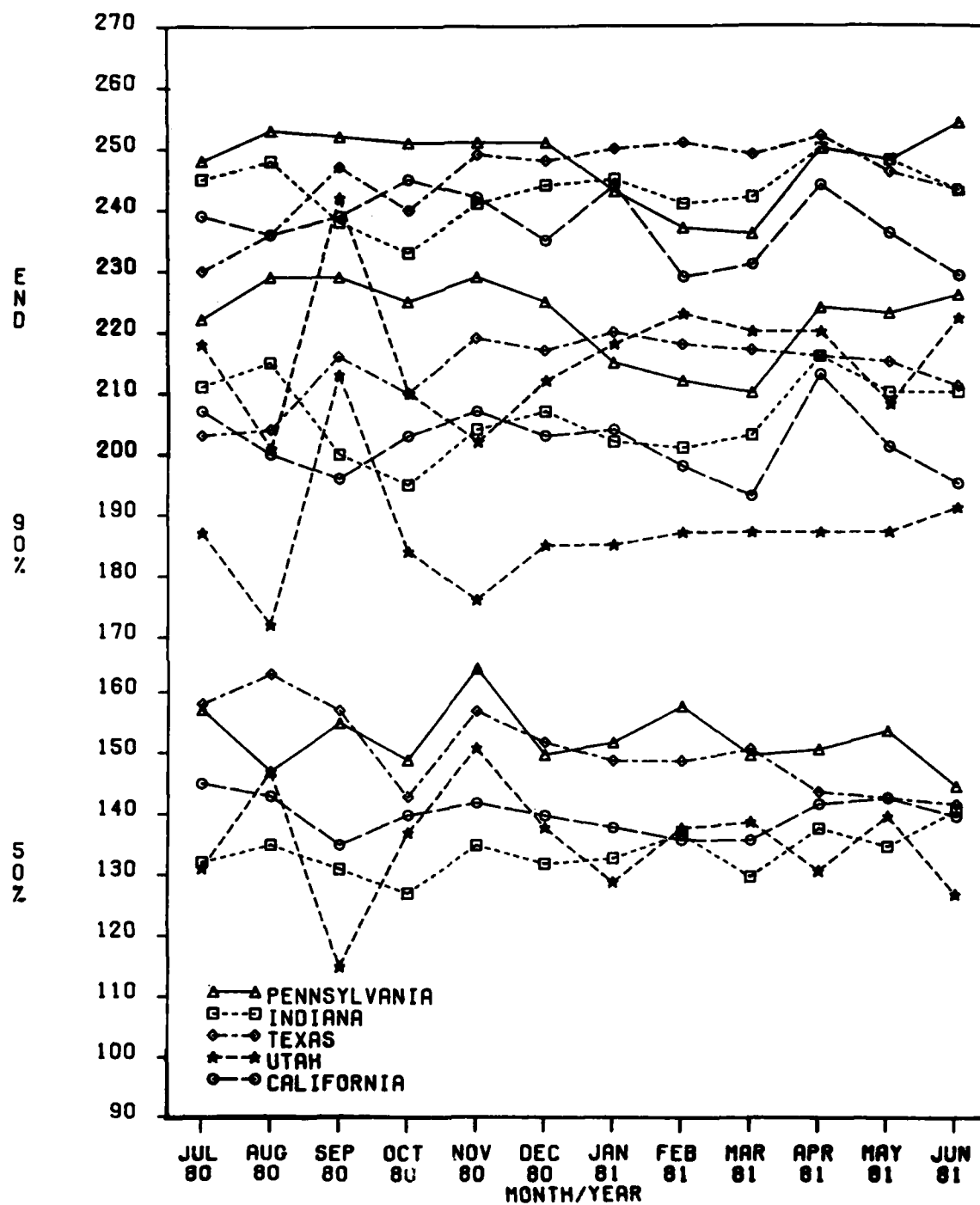


Figure 102. Boiling Range Distribution by D 86 Distillation:
Seasonal Trends

SECTION VI

1980 - 1981 "AVERAGE JP-4"

This section of the report lists the "average" properties of JP-4 for the period of July 1980 through June 1981. These properties are listed in Table 10. The table contains all the tests required in the specification and analyzed in this report, as well as, the upper and lower specification requirements, the average value of the property worldwide (arithmetic average of all the data), the value which is ten percent of the specification requirement upper limit (or a value close that was chosen for the author's convenience), the number of lots of fuels which fall between the specification lower requirement (or a logical lower limit) and ten percent of the specification upper requirement, the percentage of the total fuel lots between the lower specification requirement and ten percent of the specification upper requirement, the value which is 90 percent of the specification upper requirement, the number of lots of fuels between 90 percent of the specification upper limit and the upper specification requirement, and the percentage of the fuel samples which fall between 90 percent of the upper specification requirement and the upper specification limit. An example of this is the total acid number. There is no lower specification lower requirement though 0.000 is the reasonable lower limit. 0.015 mg KOH/g is the specification upper requirement. The average value of this property worldwide is 0.005 mg KOH/g. The value of the test results which is ten percent of the upper specification requirement is 0.0015. Two hundred and twelve lots of fuel had a total acid number between 0.000 and 0.0015 mg KOH/g. This represents 11 percent of the total lots of fuel. The value which is 90 percent of the upper specification limit is 0.0135 mg KOH/g. Thirty-two lots of fuel have a total acid number between 0.0135 and 0.015 mg KOH/g. This represents two percent of the total lots of fuel.

TABLE 10
"AVERAGE" PROPERTIES OF JP-4 FOR 1980-1981

Property	Specification Lower Limit	Specification Upper Limit	"Average Value"	Lower Specification Limit to 10% of Upper Specification Limit			90% of the Upper Specification Limit to the Upper Specification Limit		
				Value	Number of Lots	Percentage	Value	Number of Lots	Percentage
Total Acid Number (mg KOH/g)	---	0.015	0.005	0.0015	212	11	0.0135	32	2
Volume Percent Aromatics	---	25.0	12.6	2.5	22	1	22.5	18	.9
Volume Percent Olefins	---	5.0	0.8	0.5	746	37	4.5	0	0
Weight Percent Mercaptan Sulfur	---	0.001	0.0004	0.0001	508	40	0.0009	112	9
Weight Percent Total Sulfur	---	0.40	0.04	0.04	1586	79	0.36	1	0
D86 Distillation Initial Boiling Point °C	---	---	61	24 ⁽¹⁾	7	.4	103 ⁽²⁾	2	.1
D86 Distillation 10% Recovered °C	---	---	94	38 ⁽³⁾	6	.3	125 ⁽⁴⁾	62	3
D86 Distillation 20% Recovered °C	---	145	107	45 ⁽⁵⁾	5	.3	145 ⁽⁶⁾	90	5
D86 Distillation 50% Recovered °C	---	190	143	57 ⁽⁷⁾	2	.1	190 ⁽⁸⁾	107	5
D86 Distillation 90% Recovered °C	---	245	205	75 ⁽⁹⁾	2	.1	245 ⁽¹⁰⁾	596	30
D86 Distillation Final Boiling Point °C	---	270	238	81 ⁽¹¹⁾	1	.1	270 ⁽¹²⁾	1118	56
API Gravity	45.0	57.0	54.2	49.8	58	3	51.0	1960	94
Reid Vapor Pressure (psi)	2.0	3.0	2.6	2.2	162	8	2.8	371	18
Heat of Combustion (BTU/lb)	18400	---	18702	18450 ⁽¹³⁾	2	.1	18900 ⁽¹⁴⁾	12	.6
Weight Percent Hydrogen	13.6	---	14.3	13.74 ⁽¹⁵⁾	65	3	15.0 ⁽¹⁶⁾	27	1

TABLE 10 (Continued)

Property	Specification Lower Limit	Specification Upper Limit	"Average Value"	Lower Specification Limit to 10% of Upper Specification Limit			90% of the Upper Specification Limit to the Upper Specification Limit		
				Value	Number of Lots	Percentage	Value	Number of Lots	Percentage
Smoke Point (mm)	20.0	---	26.9	22.0 ⁽¹⁷⁾	231	13	40 ⁽¹⁸⁾	1	0
Thermal Stability Pressure Drop	---	25.0	0.3	2.5	1889	97	22.5	1	0
Thermal Stability Tube Deposit Code	---	3	1	---	---	---	---	---	---
Existent Gum (mg/100ml)	---	7.0	0.8	1.4	1815	90	6.3	1	0
Particulate Matter(mg/l)	---	1.0	0.4	0.1	337	17	0.9	43	2
WSIM	70	---	87	76	401	21	91	912	47
Fuel System Icing Inhibitor	0.10	0.15	0.13	0.105	168	10	0.135	214	13
Fuel Electrical Conductivity	200	600	326	240	23	30	560	3	4

- (1) All samples with an initial boiling point between 0-24 °C.
- (2) All samples with an initial boiling point between 91-103 °C.
- (3) All samples D86 distillation 10 percent recovered temperature 0-38 °C.
- (4) All samples D86 distillation 10 percent recovered temperature 112-125 °C.
- (5) All samples D86 distillation 20 percent recovered temperature 0-45 °C.
- (6) All samples D86 distillation 20 percent recovered temperature 130-145 °C.
- (7) All samples D86 distillation 50 percent recovered temperature 0-57 °C.
- (8) All samples D86 distillation 50 percent recovered temperature 171-190 °C.
- (9) All samples D86 distillation 90 percent recovered temperature 0-75 °C.
- (10) All samples D86 distillation 90 percent recovered temperature 0-75 °C.
- (11) All samples D86 distillation final boiling point 0-81 °C.
- (12) All samples D86 distillation final boiling point 243-270 °C.
- (13) All samples heat of combustion 18400-18450 Btu/lb.
- (14) All samples heat of combustion 18850-18900 Btu/lb.
- (15) All samples hydrogen content 13.6-13.74 weight percent hydrogen.
- (16) All samples hydrogen content 14.86-15.0 weight percent hydrogen.
- (17) All samples smoke point 20.0-22.0 mm.
- (18) All samples smoke point 38.0-40.0 mm.

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